AD 283 805

NAVWEPS REPORT 7904
NOTS TP 2910
COPY 98

TEMPERATURE ENVIRONMENTS OF JET FIGHTER AND ATTACK BOMBER AIRCRAFT INSTRUMENTATION

by

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ABSTRACT. A series of tests was carried out to define more clearly the extreme temperature environments to which aircraft instrument indicators and sensors in Fleet operational aircraft would be subjected. The hot-weather work was done on A4D and F-84 aircraft; the cold-weather work was done on an F9F aircraft. Extremes in temperature were obtained by keeping the canopies of the aircraft sealed and locked. During the summer, the hot-weather test aircraft were parked so that the maximum effects of the sun's rays would be obtained in the cockpit. Snow and ice were kept off the cold-weather test aircraft so that maximum radiation from the cockpit would be obtained.

The report includes 7 tables and 40 graphs. Weather parameters are touched upon as they definitely affect extreme temperatures. The effect of the vertical temperature gradient in the cockpit is discussed also.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

August 1962

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

C. BLENMAN, JR., CAPT., USN, Commander
WM. B. MCLEAN, PH.D., Technical Director

FOREWORD

Aircraft instrumentation plays an important part in the work being done to keep naval aircraft and aviators efficient and effective. From this basis, research work is being carried out to keep the specifications of proposed aircraft instruments up to date and applicable to the uses for which they are being planned.

In 1960, a proposed MIL-STD was drawn up based on these studies. The work described in this report was carried out to verify the aircraft-instrument-temperature parameters set forth in this MIL-STD, and to revise the data wherever necessary.

During the summer of 1960, intensive work was begun by the U. S. Naval Ordnance Test Station to gather data on the probable maximum temperatures to which cockpit-mounted instruments would be subjected under locked, sealed canopy conditions. Companion winter studies were carried out in winter 1961–62 to explore the cold-weather portion of the temperature parameter.

This work was supported by Task Assignment RREN-ST-307-216-0000-00-000. The report has been reviewed for technical accuracy by Colin A. Taylor, Head, Product Evaluation Branch.

Released by
FOY MC CULLOUGH, JR., Head,
Test & Evaluation Div.
7 March 1962

Under authority of
J. T. BARTLING, Head,
Propulsion Development Dept.

NOTS Technical Publication 2910
NAVWEPS Report 7904

Published by . . . . Publishing Division
Technical Information Department
Collation . . . . Cover, 28 leaves, abstract cards
First printing. . . . . .215 numbered copies
Security classification . . . . UNCLASSIFIED

ACKNOWLEDGMENT

The author is indebted to and wishes to thank Colonel Richard P. Wittman and the personnel of the U. S. Army Office of Research and Development, Alaska, for their help in facilitating the gathering of data during the winter series of tests; the personnel of the Naval Parachute Facility, El Centro, Calif., for the help they gave during the summer portion of the test series; Colin A. Taylor, Head, Product Evaluation Branch, for his continued guidance and help with test techniques used throughout the study; and Stuart O. Lilly, Technical Information Department, for his continuing help in the technical editing of the reports published throughout the environmental test series.

CONTENTS

INTRODUCTION

The environmental patterns used to set the temperature parameters to which aircraft instrumentation must qualify have been pieced together over the years. A study has been needed to ascertain definitely these parameters. Most of the temperature criteria and the time durations used in testing aircraft instruments have been set by using data accumulated from sources of information gathered for other purposes. In some cases, this has led to requirements far too severe when compared with the actual uses of the particular instruments. There also has been an apparent misunderstanding of weather data in the assignment of temperature minimums to some aircraft instrumentation. The combination of these facts necessitated the establishment of a reliable correlation between existing data and actual aircraft service environments.

The hot-weather qualifying temperature for aircraft instrumentation, which has been designated as 160°F, seems much more severe than necessary for non-heat-producing cockpit-mounted aircraft instruments. The cold-weather environment for aircraft instrumentation has been designated as -65°F with a trend toward -80°F. The findings from the cold-weather studies reported herein indicate that this designation is too severe for aircraft instrumentation. If these lower temperatures are to be used, the time duration of instrument subjection during testing should be revised completely.

PROCEDURES

T: SITES

Two sites for maximum-temperature tests on cockpit instrumentation were chosen: the Naval Air Facility at the Naval Ordnance Test Station (NOTS), China Lake, Calif., as typical of high-desert weather conditions[1]; and the Naval Parachute Facility (NPF), at the Naval Landing Field, El Centro, Calif., as typical of low-desert weather conditions. Elevation at the NOTS site was 2,218 feet; at the NPF site, 45 feet below sea level.

Several sites were considered for the series of cold-weather tests, including Thule, Greenland; Cole RCAF Station, Canada; Fort Churchill, Canada; Fort Greely, Alaska; and Fort Wainwright, Alaska. Studies of weather history during the past 40 years indicated that Alaskan temperatures were equal to or lower than temperatures at the Greenland and Canadian locations. When the facilities of the Army's Ordnance Arctic Test Activity (OATA) at Fort Wainwright were offered to NOTS for these tests, they were studied and found desirable. The Fort is located

[1] Geophysical data have shown that China Lake (the Indian Wells Valley region) has the highest solar radiation intensities reported in the United States. Phoenix, Ariz., is ranked second.

outside Fairbanks, Alaska, at an altitude of about 440 feet. The Chena River runs through the Fort's lowland, forming a swampy area during the summer, which freezes during the winter. Cold air from the surrounding higher ground drains into this area, providing lower temperatures than are recorded at nearby Fairbanks International Airport. This low-temperature area provides the most severe environmental conditions to which an exposed aircraft could be subjected.

TEST VEHICLES

Preliminary environmental tests for the maximum-temperature test program were made in an F-84 aircraft (Fig. 1). These preliminary tests, which began 16 June 1960, constituted Phase I of a two-phase summer program and established procedures for the over-all program.

An A4D light attack bomber was used for Phase II because of the aircraft's half-bubble canopy as opposed to the F-84's full-bubble canopy. Available for use as a test vehicle was an A4D cockpit that had been used in tests at the NOTS Supersonic Naval Ordnance Research Track for the Mk 1 Mod 0 Rocket Catapult Qualification Program. A nonoperational (struck) A4D aircraft was also available.

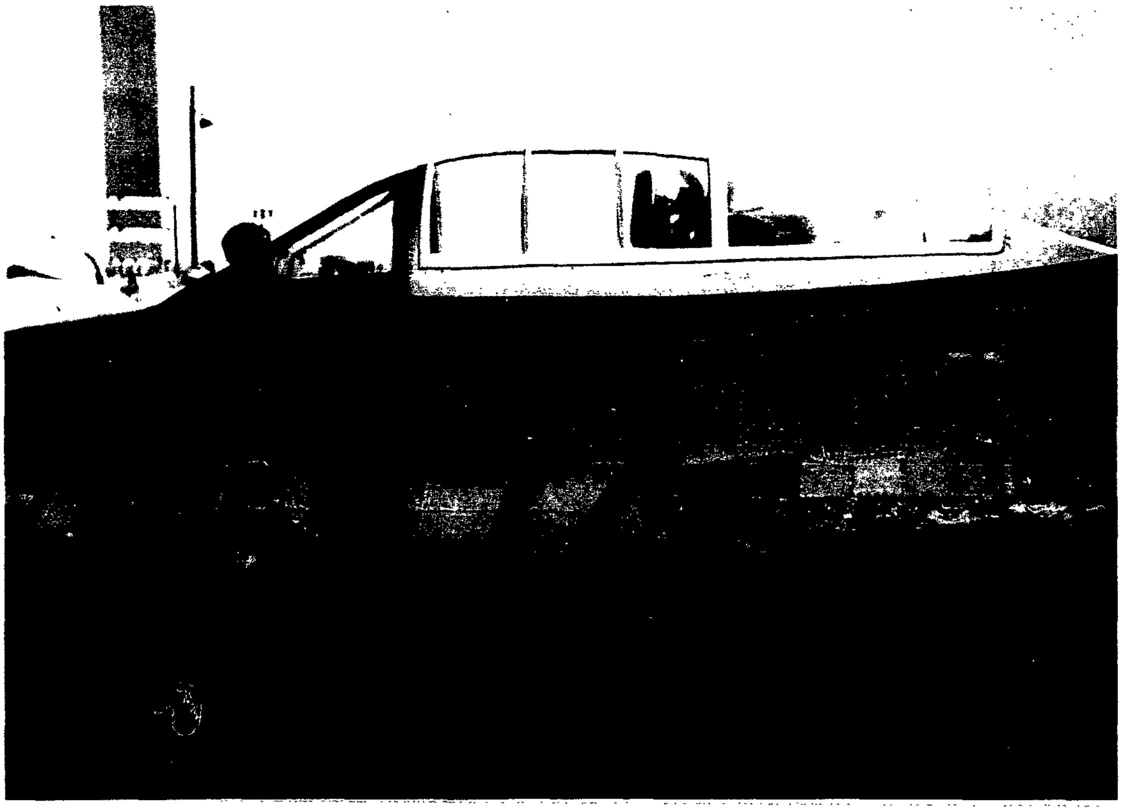

FIG. 1. F-84 Test Vehicle at NOTS.

In order to ensure the same hardware parameters at both summer test sites, the cockpits were rebuilt similarly and new canopies installed. The cockpit system of the vehicle at NOTS consisted of a regulation A4D fuselage cut off behind the fuel cell (Fig. 2). The second vehicle, the struck A4D (Fig. 3), was set up at NPF. The F-84 was set up at NOTS about 2 miles from the A4D.

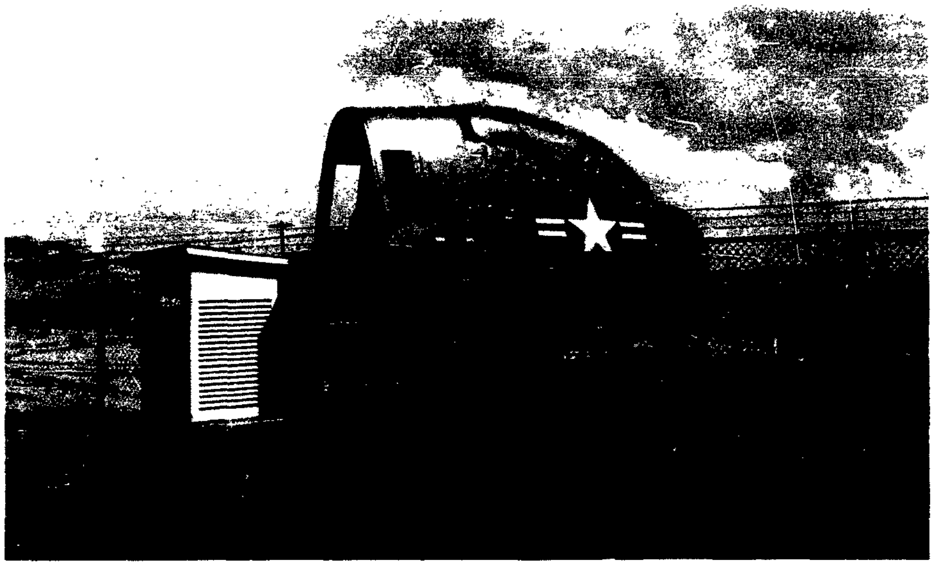

FIG. 2. A4D Test Vehicle at Naval Air Facility, NOTS.

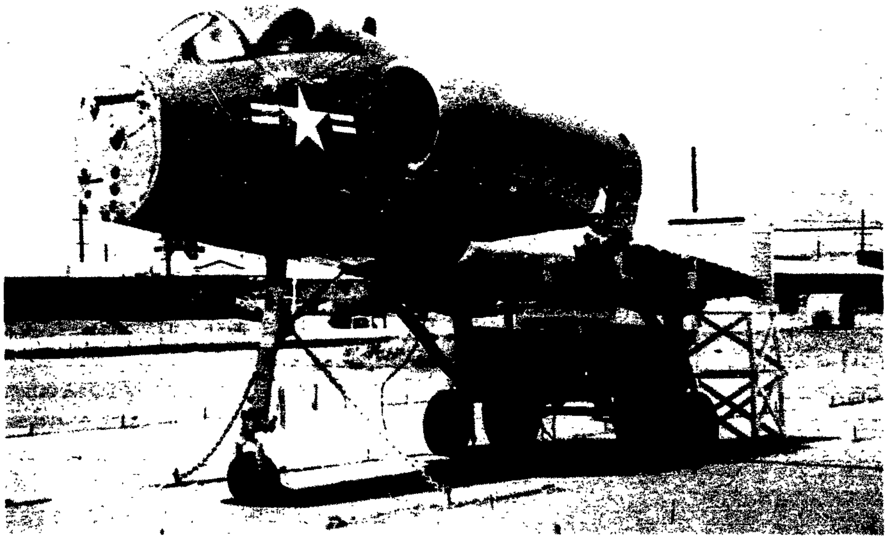

FIG. 3. A4D Test Vehicle at Naval Parachute Facility, El Centro.

Phase II tests began at NPF on 28 June 1960 and at NOTS on 14 July 1960. The canopies on both vehicles were locked and sealed shut, making the cockpits airtight. This resulted in the most extreme temperature conditions.

The arctic series test vehicle was an F9F-6P aircraft (Fig. 4). The F9F cockpit was prepared in accordance with the requirements set for the summer tests. The F9F has a full-bubble canopy similar to the F-84. This was expected to allow the maximum radiation of heat from the cockpit components and dashboard instruments, thereby giving possibly lower

FIG. 4. F9F Test Vehicle at Fort Wainwright, Alaska.

exposure temperatures than would be expected in a half-bubble-canopy-equipped aircraft like the A4D.

Figure 4 is a composite of three photographs showing the "lay of the land" at the arctic test site. Notice the flatness of the land and the low, scattered foliage. The top view shows scrub trees, which were to the west of the test site. Fairbanks International Airport, the site of the Weather Bureau Station, is about due west of this position. The center picture was taken facing south. The brightness in the sky is the glow of the sun through the overcast. This view was taken at about 1300 hours when the sun was at its highest point during the day. Notice the snow cover on the canopy and windshield of the aircraft in this and the bottom view. This cover, if not removed, caused the thermal gradient in the cockpit from floor to canopy to diminish greatly. When the relatively warm aircraft was positioned out of the hangar, a thin coat of slick ice formed over the aircraft within a few hours. This ice layer tended to cloud the canopy, which, in turn, tended to reflect cockpit heat being radiated into the sky.

INSTRUMENTATION

Standard Minneapolis-Honeywell strip-chart 12-point recorders and Universal 24-point recorders were used to gather the temperature data. At each desert test site, one 12-point recorder for each aircraft was installed in a well ventilated instrument shelter to shield the recorders from the heat. In the arctic, a 12-point and a 24-point recorder were installed in a well heated instrument shelter to shield the instruments from the intense cold. Zener diode standardization was used on all the recorders to negate temperature effects inherent in a battery-standardized instrument. Before either test series was started, the instruments were certified to be accurate to 0.25% full-scale deviation, or within ±2°F. At the end of the tests, the instruments were recalibrated with no variation noted.

THERMOCOUPLES

The cockpits were instrumented with copper–constantan thermocouples consisting of a 0.375-inch-square piece of copper 0.005 inch thick, silver-soldered to the spread thermocouple wire ends. At each location in the cockpit, the copper plate was formed to fit the surface of interest and held against the surface by pressure from the 20-gage thermocouple wire leads taped in place 1/2 to 2 inches away from the copper plate. The flat plate averaged the temperature reading over the 0.375-inch square.

The thermocouple lead wires were soldered into a cannon plug located in a position in each aircraft that was protected from rapid temperature changes. Extension lead wires of similar 16- or 20-gage thermocouple wire were brought to the recording instruments.

Thermocouples were installed in the A4D at NOTS as shown in Fig. 5, with locations numbered as follows:

1. Inside canopy, exposed
2. In air, 50 inches above cockpit floor, exposed
3. 46 inches above cockpit floor, shielded
4. 36 inches above cockpit floor, shielded
5. 26 inches above cockpit floor, shielded
6. 16 inches above cockpit floor, shielded
7. 6 inches above cockpit floor, shielded
8. 1 inch above cockpit floor, shielded
9. On dashboard, centered
10. Inside parachute pack, shoulder strap opening

Thermocouples were installed in the A4D at NPF as shown in Fig. 5 with the locations numbered as follows:

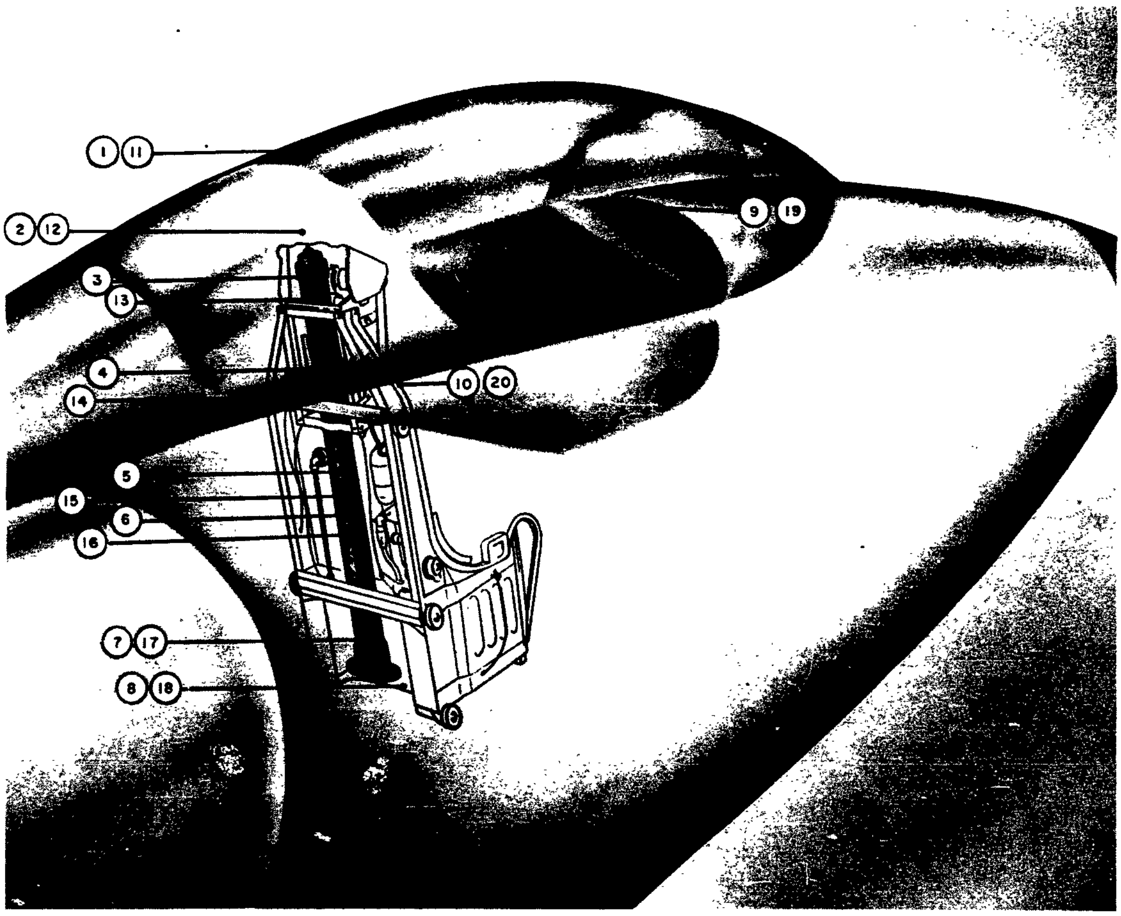

FIG. 5. Thermocouple Locations on A4D Test Vehicle, NOTS and NPF.

11. Inside canopy, exposed
12. In air, 50 inches above cockpit floor, exposed
13. 42 inches above cockpit floor, shielded
14. 31 inches above cockpit floor, shielded
15. 21 inches above cockpit floor, shielded
16. 17 inches above cockpit floor, shielded
17. 6 inches above cockpit floor, shielded
18. 1 inch above cockpit floor, shielded
19. On dashboard, centered
20. Inside parachute pack, shoulder strap opening

The thermocouples in the F-84 aircraft were installed in similar locations to those in the A4D aircraft and are numbered as follows (Fig. 6):

21. Inside top of canopy, exposed
22. In air, above the seat headrest, exposed
23. In air, top of seat, shielded
24. In air, 1/3 the distance down from top of seat, shielded
25. In air, 2/3 the distance down from top of seat, shielded
26. In air, bottom of seat, shielded
27. In air, on cockpit floor
28. On dashboard, centered
29. Outside top of canopy

The thermocouples installed in the winter test vehicle are shown in Fig. 7, with locations numbered as follows:

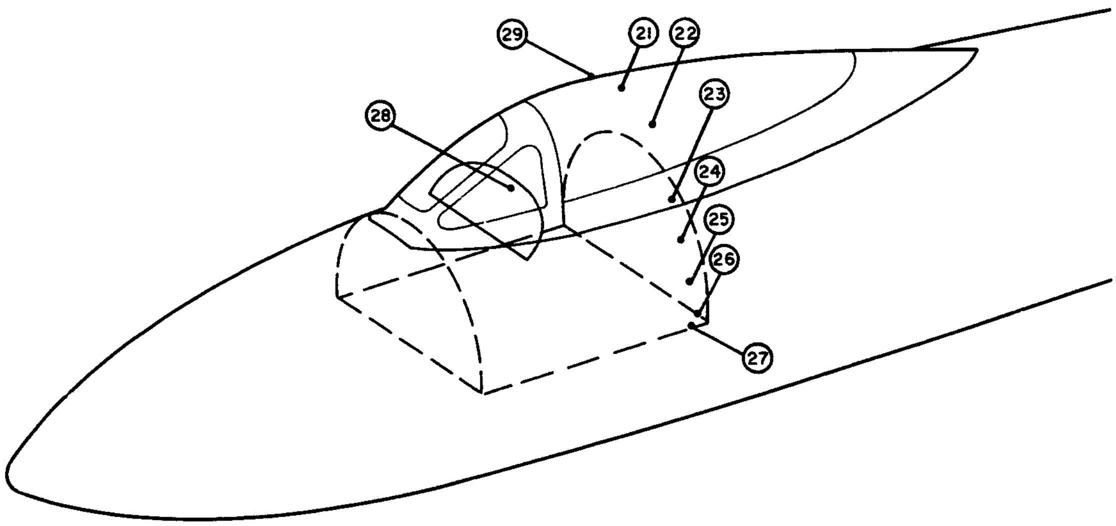

FIG. 6. Thermocouple Locations on F-84 Test Vehicle, NOTS.

1. Top skin, inside nose
2. Inside nose, 2 1/2 inches from top
3. Inside nose, 12 1/2 inches from top
4. Inside nose, 22 1/2 inches from top
5. Inside nose, 12 1/2 inches from bottom
6. Inside nose, 2 1/2 inches from bottom
7. Bottom skin, inside nose
8. Top inside of canopy
9. 2 1/2 inches from top of canopy
10. 12 1/2 inches from top of canopy
11. 22 1/2 inches from top of canopy
12. 32 1/2 inches from top of canopy
13. Floor of cockpit
14. Roof of nose-wheel well
15. 7 inches from top of nose-wheel well
16. 17 inches from top of nose-wheel well
17. Bottom of nose-wheel well
18. Top inside of canopy (shielded from radiation)
19. 2 1/2 inches from top of canopy (shielded from radiation)
20. 12 1/2 inches from top of canopy (shielded from radiation)
21. 22 1/2 inches from top of canopy (shielded from radiation)

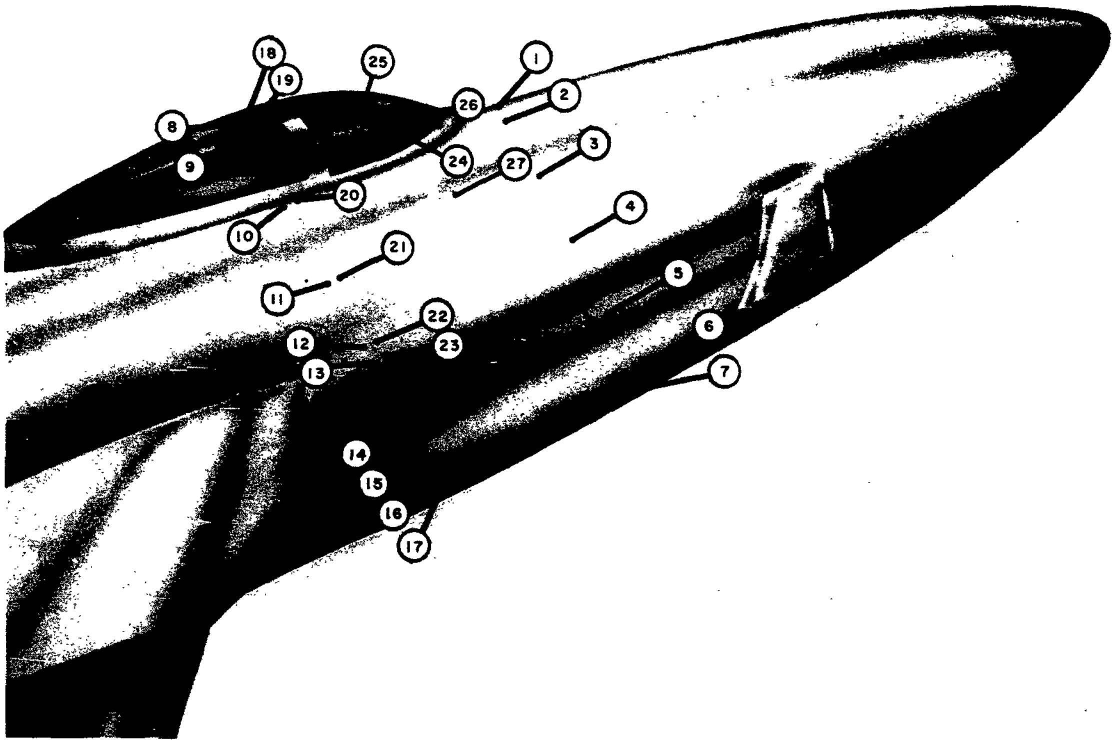

FIG. 7. Thermocouple Locations on F9F Test Vehicle, Fort Wainwright.

22. 32 1/2 inches from top of canopy (shielded from radiation)
23. Floor of cockpit (shielded from radiation)
24. On dashboard, right side
25. On dashboard, left side
26. On dashboard, top center
27. On dashboard, bottom center

TEST PRELIMINARIES

The hot-weather A4D test aircraft were parked with their noses pointed south to gain the maximum canopy and windshield surface exposure to the normal rays of the sun. The A4D canopy has a transparent area of about 1,400 in^2. The metal fuselage of the A4D meets the Plexiglas canopy at a point about 10 inches behind the pilot's head. The F-84 test aircraft was parked with the nose pointing north to ascertain the difference in temperatures that would result from parking the aircraft in a different direction. The normal rays of the sun were, to some extent, reflected off the slope of the rear half of the F-84's full-bubble canopy and also were blocked by the armor plate behind the seat and the high headrest on the seat.

The cold-weather F9F test aircraft was parked with the nose pointed north to gain the minimum canopy and windshield surface exposure to the normal rays of the sun. The F9F canopy has a transparent area of about 3,000 in^2. Actually, the sun's rays do not impinge on very much canopy area during the arctic winter because of the shallow angle the sun makes with the horizon (Fig. 8).

FIG. 8. Sun at Its Zenith During Typical Winter Test-Series Day.

Each test vehicle was equipped and, in effect, poised as if the aircraft were on the ready line. For the purpose of these tests, however, the canopies were completely closed, locked, and sealed. This served to simulate the most extreme temperature conditions. (Aircraft are not customarily parked on desert airfields with the canopy closed, but sometimes are when bad weather seems imminent.)

The more rigorous conditions established for the test program promised to result in temperatures comparable to the extremes that any aircraft might experience during Fleet service.

PROCESSING OF TEST DATA

SUMMER

Tests were conducted on the F-84 aircraft during 96 consecutive days. Usable data were collected on 89 days. Power failure to the recorder and a thunderstorm either partially or completely negated efforts on 21 and 22 July, and 3, 4, 5, 6, and 16 August 1960. On the A4D aircraft, tests were conducted on 67 consecutive days. Usable data were collected on 63 days. Power failures to the recorder resulted in partial loss of data on 4 days. When charts were prepared for the thermocouple locations, maximum temperature readings were plotted for the 67 days beginning 14 July 1960, with the exception of 21, 22, and 30 July and 13 September 1960. Similar plots were prepared on the maximum temperatures recorded at NPF, where testing began late in June 1960. These plots cover 70 days.

Correlation With Weather. Accurate weather data were recorded continuously over the course of the test periods to aid in the analysis and interpretation of the temperature readings taken at each test site. At NOTS, control-tower weather data were provided by the weather room of the Naval Air Facility. The data were collected at 2,268 feet altitude. At NPF, the control tower at the Naval Auxiliary Landing Field provided similar weather data, collected at 29 feet below sea level. Both are official U. S. Weather Bureau reporting stations. A table of these prevailing weather conditions and comments on their effects are presented in Appendix A.

In all probability, the maximum cockpit temperatures for the year were realized at both test sites. The record of daily maximum ambient temperatures reported at NOTS between 10 June and 18 September 1960 showed 57 days at 100°F or higher with a maximum of 111°F (Fig. 9).

At NPF, a comparable record was compiled covering the days between 28 June and 3 September 1960 (Fig. 10). There were only 5 days in which the maximum ambient temperature did not reach 100°F. The highest temperature was reached on 2 days, when 120°F was recorded.

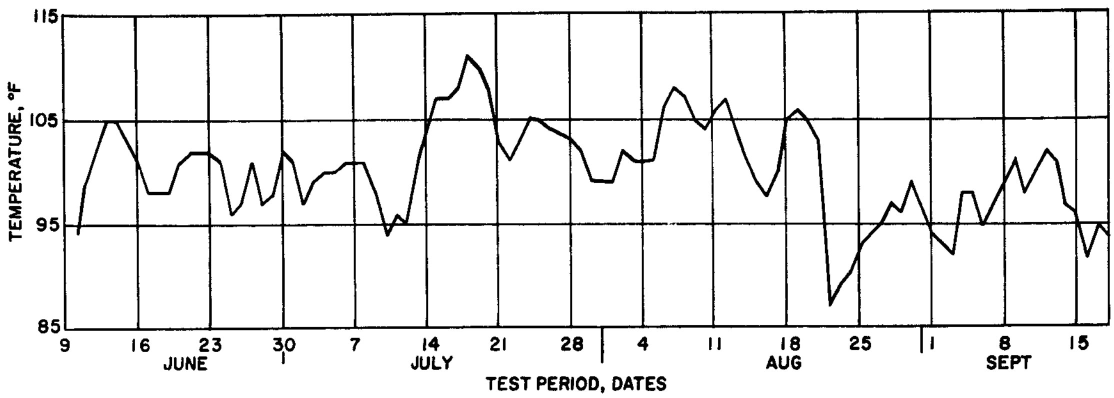

FIG. 9. Record of Daily Maximum Temperatures Reported at NOTS During Test Series.

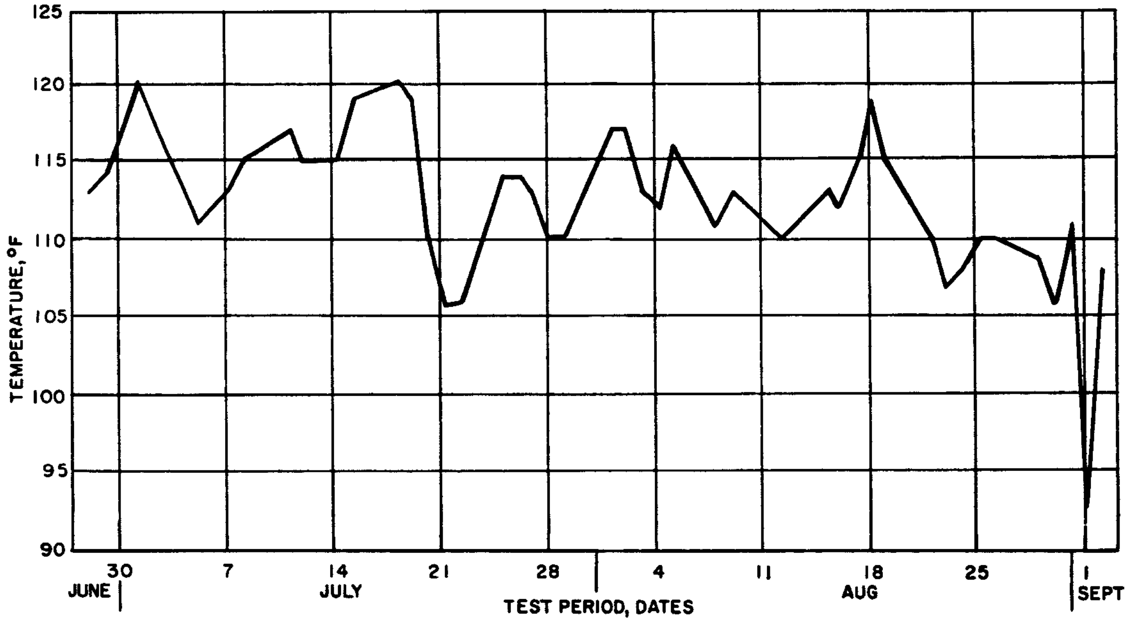

FIG. 10. Record of Daily Maximum Temperatures Reported at NPF During Test Series.

There were 15 days during the test season at NOTS when maximum temperatures at the thermocouple location on the instrument panel of the F-84 aircraft exceeded 160°F. The comparable record at NPF was 2 days with the maximum temperatures above 160°F. The A4D at NOTS underwent 6 days with maximum temperatures on the dash panel above and 3 days with maximum temperature at 160°F.

It was decided to give detailed analyses to all days at both test sites with instrument panel temperatures above 160°F. This data cut-off temperature of 160°F was chosen, as it is the maximum temperature

given in instrument environment specifications. These analyses included a series of plots of the above mentioned days (Fig. 11-13). These figures summarize the daily maximum instrument panel temperatures for all days when temperatures exceeding 160°F were recorded.

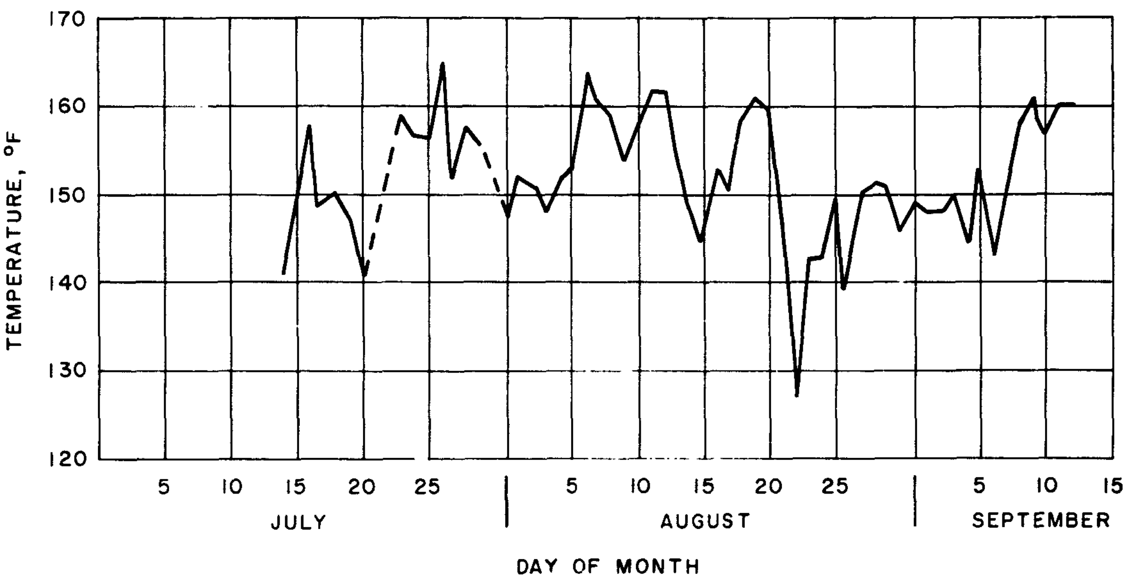

FIG. 11. Instrument Panel Temperatures, A4D Test Vehicle, NOTS.

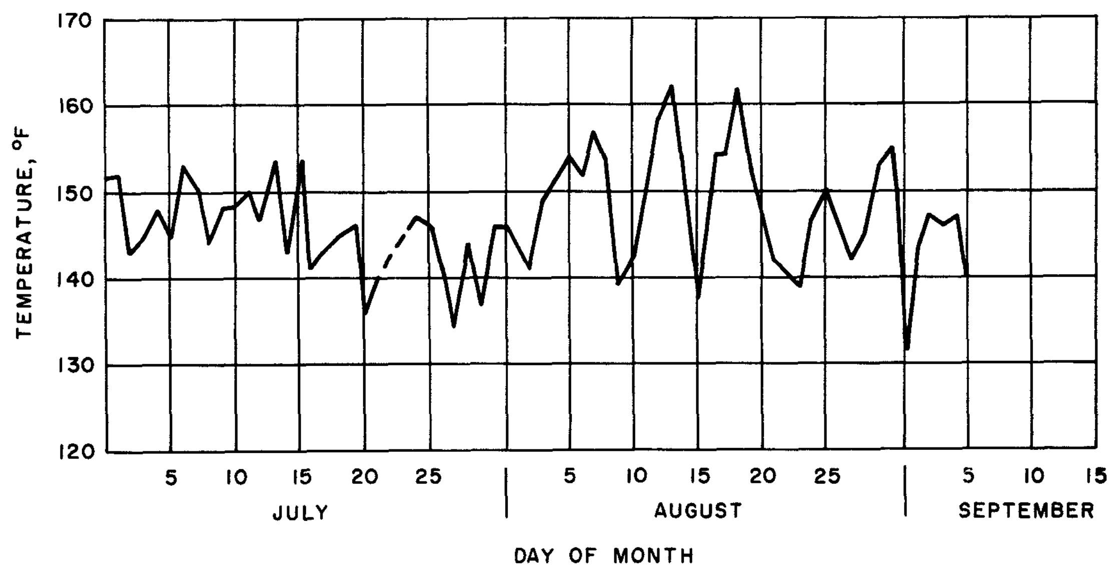

FIG. 12. Instrument Panel Temperatures, A4D Test Vehicle, NPF.

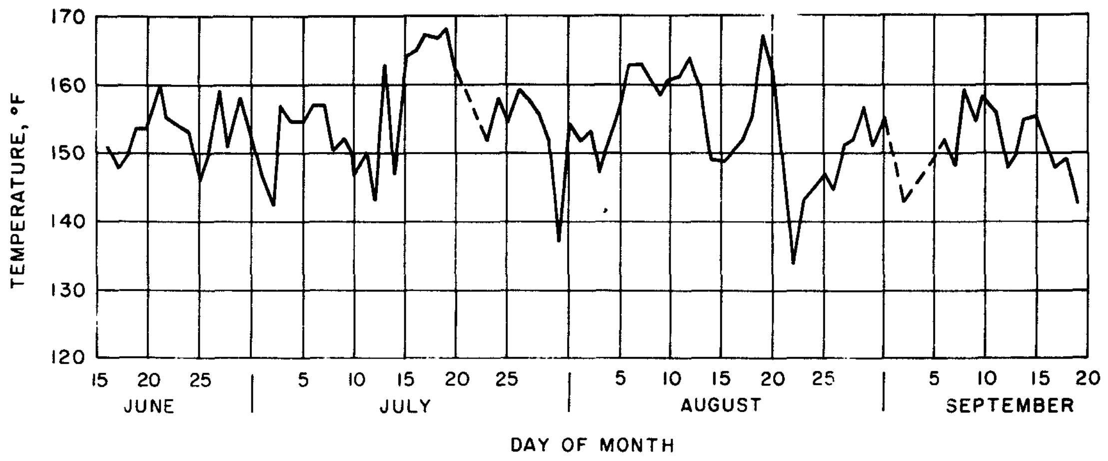

FIG. 13. Instrument Panel Temperatures, F-84 Test Vehicle, NOTS.

WINTER

Tests were conducted on the F9F aircraft at OATA during 114 consecutive days. Usable data were collected on 107 days. Power failures to the recorders resulted in partial loss of data on 7 days. Recorder malfunction resulted in further data losses, but because of the dual instrument arrangement, no nonreplaceable data were lost. When charts were prepared for the thermocouple locations, minimum temperature readings were plotted for the extreme-temperature days beginning 7 December 1961. Plots were prepared also for the cockpit and nose sections of the aircraft, as these show the over-all temperatures of the aircraft as a unit and how the instrument panel temperatures compare with them.

Correlation With Weather. Accurate weather data were recorded continuously over the course of the test period to aid in the analysis and interpretation of the temperature readings taken at the test site. OATA weather data were provided by the Signal Corps Meteorological Detachment and were collected at an altitude of 445 feet. The Weather Bureau Reporting Station at Fairbanks International Airport also provided official weather readings for that location.

RESULTS

SUMMER

The 21 days of maximum instrument panel temperature at NOTS and the 2 days of maximum instrument panel temperature at NPF were analyzed to show details on extreme-temperature environmental conditions that might be experienced by any cockpit-mounted instrument or indicator when installed in Fleet-service aircraft.

Temperature Gradients. Table 1 summarizes the maximum instrument panel temperature examples. It can be seen that the instrument panel fits into a rather complicated vertical thermal gradient in the cockpit of the aircraft. This gradient is composed of heat imparted to the cockpit by conduction from the outside ambient air and from solar radiation through the canopy. It can be seen, also, that the ambient air temperature need not be excessive to have elevated cockpit temperatures. The average summer temperature at El Centro (Fig. 11) is quite a bit higher than the average summer temperature at NOTS (Fig. 10). However, the majority of temperatures above the 160°F qualification temperature were recorded at NOTS. The highest instrument panel temperatures were experienced on the F-84. The two A4D test vehicles were identical in all cockpit respects with the exception of location on the earth. Even though there were 170-183°F temperatures recorded at the inside surface of the canopy of the A4D test vehicles and 154-159°F recorded at the inside surface of the canopy of the F-84 aircraft, the

TABLE 1. DISTRIBUTION OF MAXIMUM TEMPERATURES RECORDED DURING SUMMER TEST SERIES

Aircraft and date	Temperature, °F			
	Ambient	On instrument panel	Inside top of canopy	On cockpit floor
F-84, NOTS				
19 July	109	168	155	140
19 August	106	167	145	134
18 July	111	167	153	140
17 July	108	167	159	137
16 July	107	165	151	136
15 July	107	164	153	134
12 August	107	164	149	135
13 July	101	163	152	132
6 August	106	163	150	135
7 August	108	163	150	135
20 July	105	162	157	133
20 August	105	162	144	131
8 August	105	161	147	136
10 August	......	161	148	132
11 August	......	161	155	135
A4D, NOTS				
26 July	104	165	170	137
6 August	106	164	171	134
11 August	106	162	173	135
12 August	107	162	176	137
19 August	106	161	172	133
9 September..	101	161	171	135
A4D, El Centro				
13 August	......	162	182	151
18 August	119	162	183	152

instrument panel on the F-84 showed the more extreme temperatures. The cockpit gradient, therefore, must have been greater in the A4D aircraft than in the F-84 aircraft.

Maximum Temperatures. The data collected during this test series provide the maximum temperature condition to which the instrument panel in an aircraft could be subjected during a typical hot-weather period. The placement of the instrument panel thermocouple was dictated by the inherent vertical thermal gradient in the closed cockpit of a nonoperating aircraft. The top of the panel will be slightly hotter than the bottom.

With the test vehicles placed pointing either north or south, the radiation from the sun into the cockpit was most intense daily between 0900 and 1500 hours. The instrument panel of the north-pointed F-84 aircraft apparently was exposed to more direct solar radiation than the instrument panels of the south-pointed A4D aircraft. In the rest of the cockpit, the northern heading seemed to decrease the severity of the maximum temperatures. The instrument panel, though, would be directly exposed to the summer sun through the canopy.

Figures 14–36 show graphically the 23 days where the recorded temperature at the instrument panel was 160°F or higher. The first 4 days in order of occurrence are from the north-pointed F-84 aircraft. The south-pointed A4D test vehicles account for only 8 of the 23 days. By integration, it can be seen that the area under the curves of these figures varies quite a bit. If the early-morning pattern indicated on some low-temperature examples had continued throughout the day, even higher instrument panel temperatures could have been realized. It can be seen that meteorological parameters have an important effect on the maximum cockpit temperatures in closed, inoperative aircraft. It should be noted that the majority of the curves are not smooth. The hourly temperature fluctuations indicate that the thermal driving force is rarely constant or changing at a smooth rate. It must be remembered that these data are for inoperative, locked, sealed aircraft only. The Navy has a long-standing policy that aircraft canopies be left ajar or fully open when the aircraft is parked on a desert air field.

The difference in temperature between open and closed cockpits was recorded by Frankford Arsenal on a B-47E aircraft (Fig. 37). The tests were done at Laguna Army Air Field, Yuma Test Station, Yuma, Ariz. With an ambient air temperature of 113°F, the open-canopy cockpit air temperature at instrument-panel level was 125°F. The difference between panel temperature and outside air temperature was only 12°F. With the canopy closed, an instrument panel temperature of 160°F was recorded, with an outside ambient air temperature of only 108°F. When comparing these test situations, it can be seen that there is a difference of expected instrument panel temperatures of about 40°F between the closed cockpit condition and the open cockpit condition. The temperatures obtained from the series of tests conducted on the F-84 and A4D aircraft, therefore, can be considered the worst temperature extremes

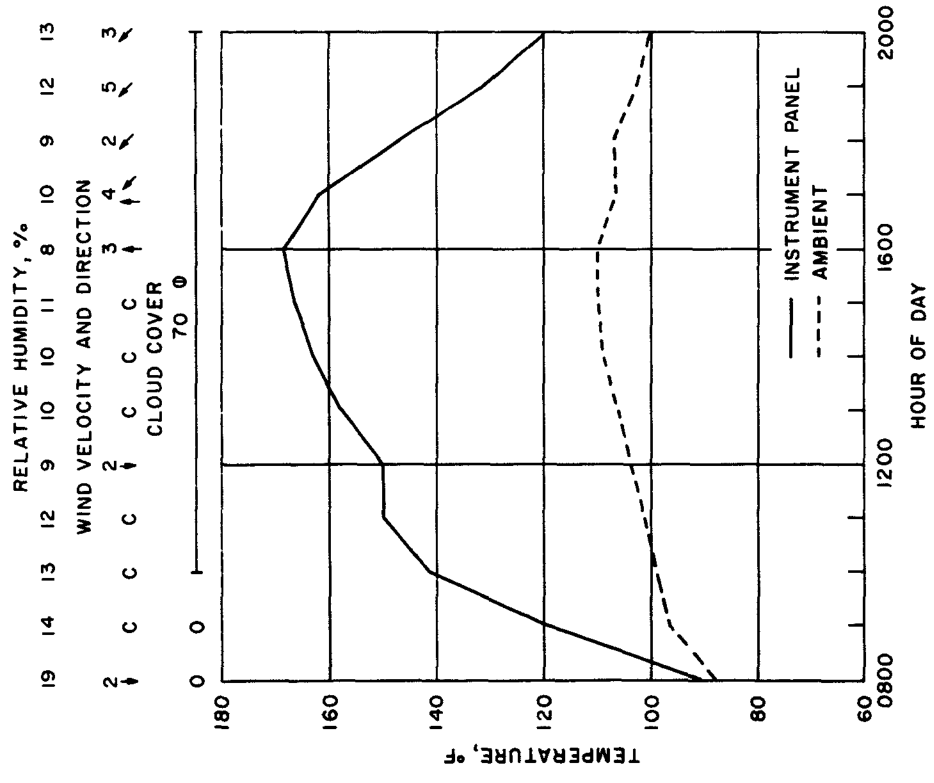

FIG. 14. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 19 July 1960, the First Day in Order of Extreme Temperatures at NOTS.

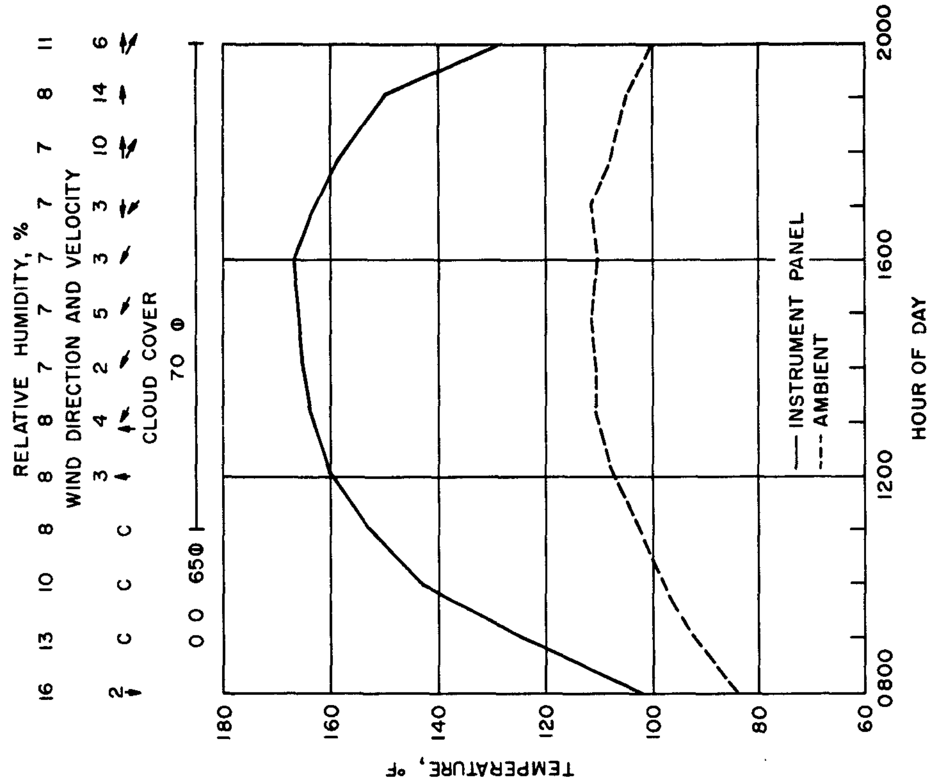

FIG. 15. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 18 July 1960, the Second Day in Order of Extreme Temperatures at NOTS.

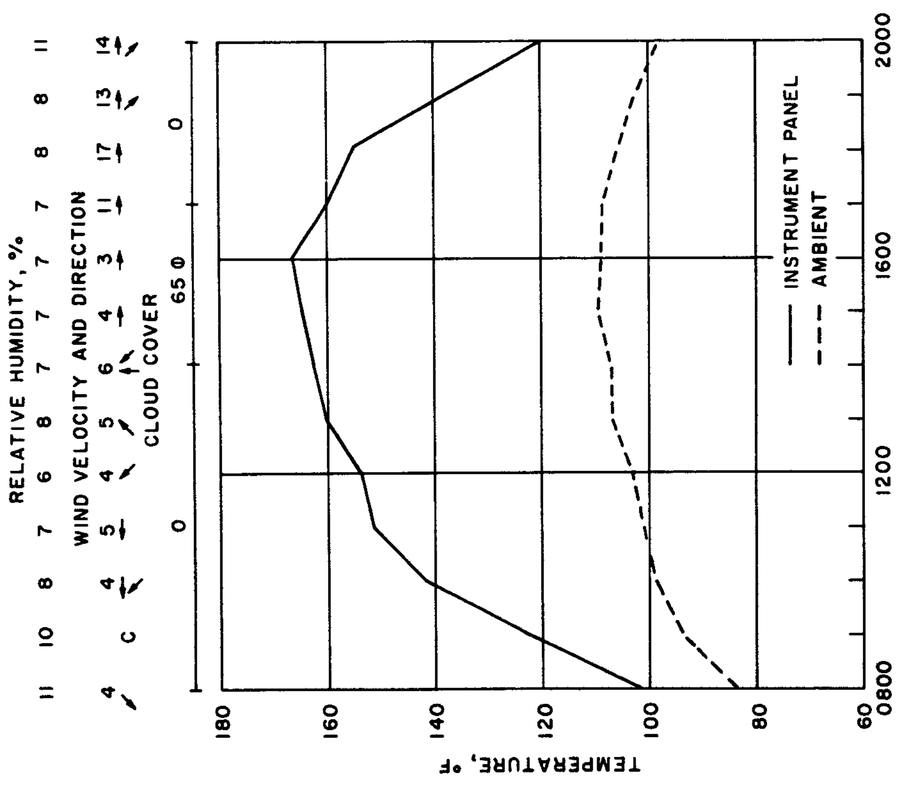

FIG. 16. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 17 July 1960, the Third Day in Order of Extreme Temperatures at NOTS.

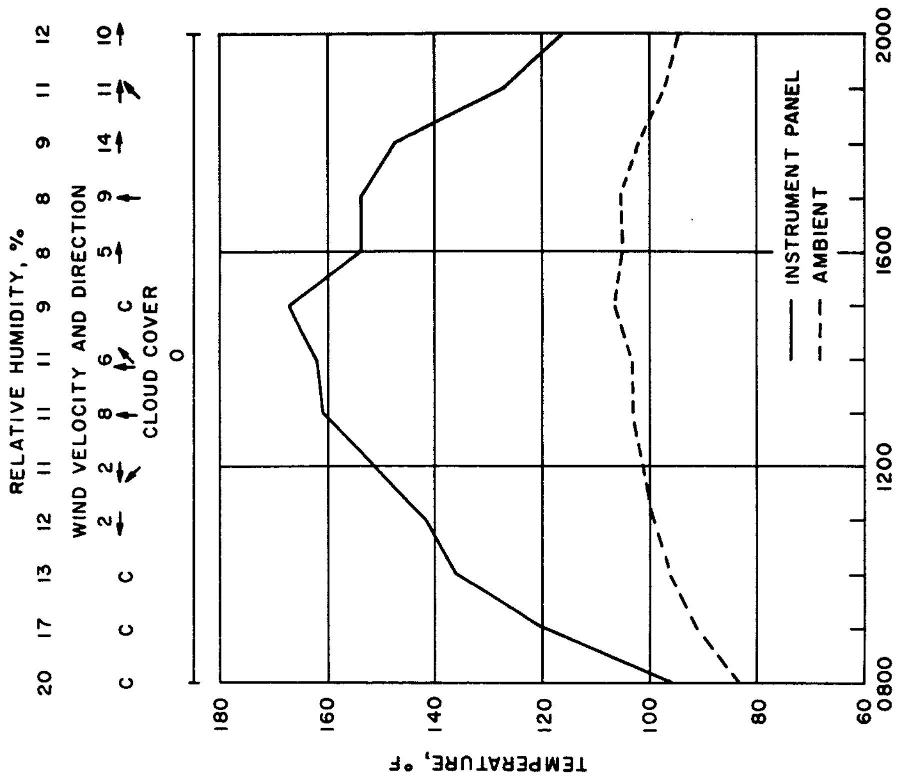

FIG. 17. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 19 August 1960, the Fourth Day in Order of Extreme Temperatures at NOTS.

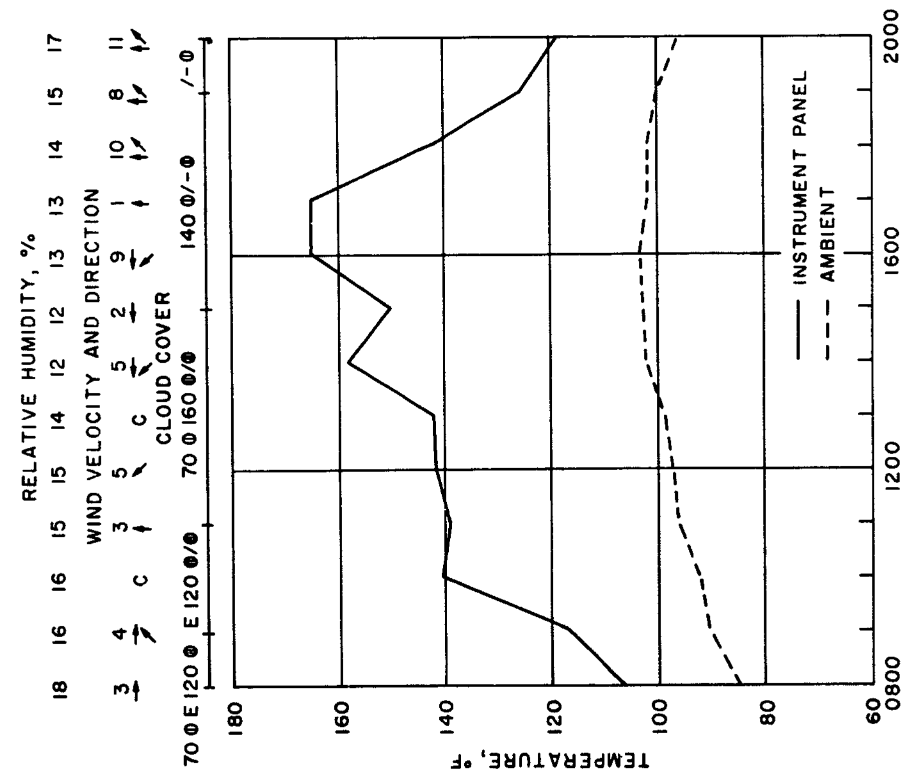

FIG. 18. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 26 July 1960, the Fifth Day in Order of Extreme Temperatures at NOTS.

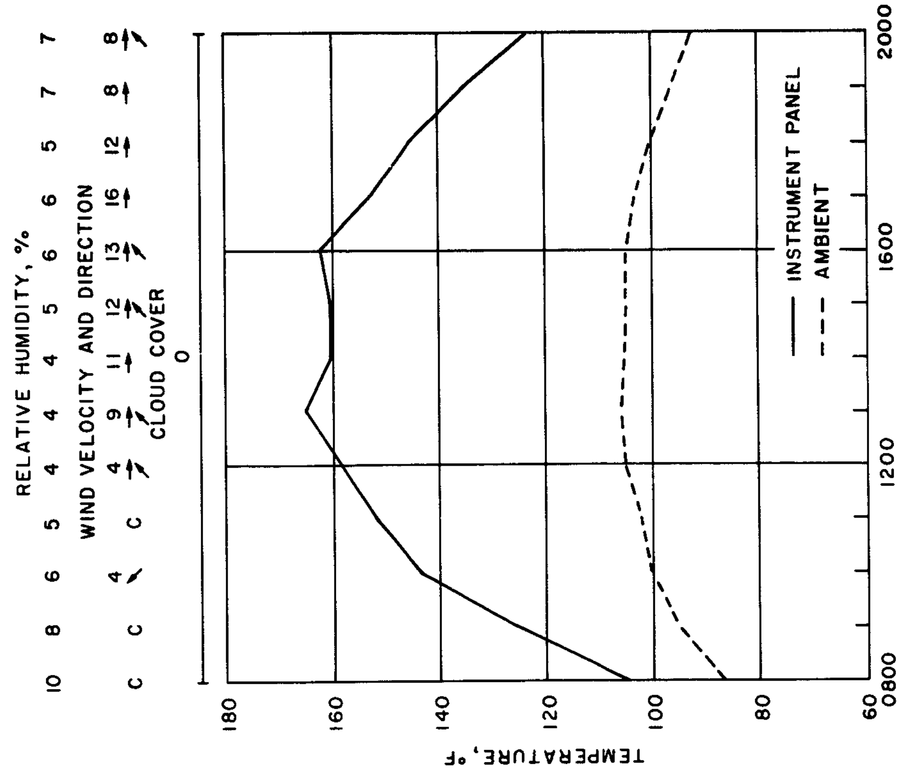

FIG. 19. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 16 July 1960, the Sixth Day in Order of Extreme Temperatures at NOTS.

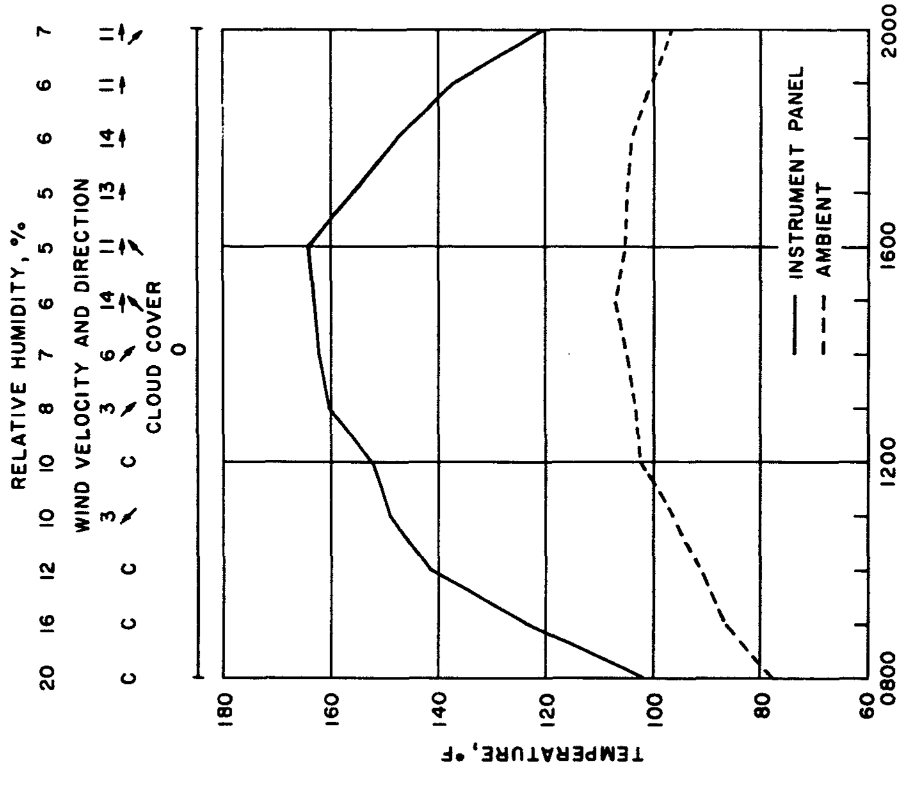

FIG. 20. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 15 July 1960, the Seventh Day in Order of Extreme Temperatures at NOTS.

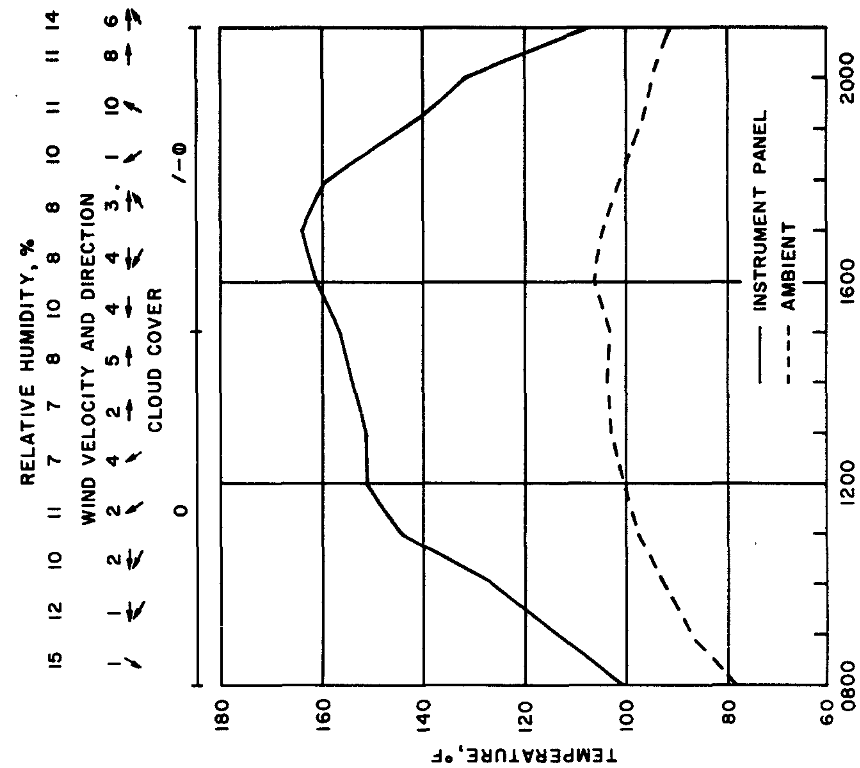

FIG. 21. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 6 August 1960, the Eighth Day in Order of Extreme Temperatures at NOTS.

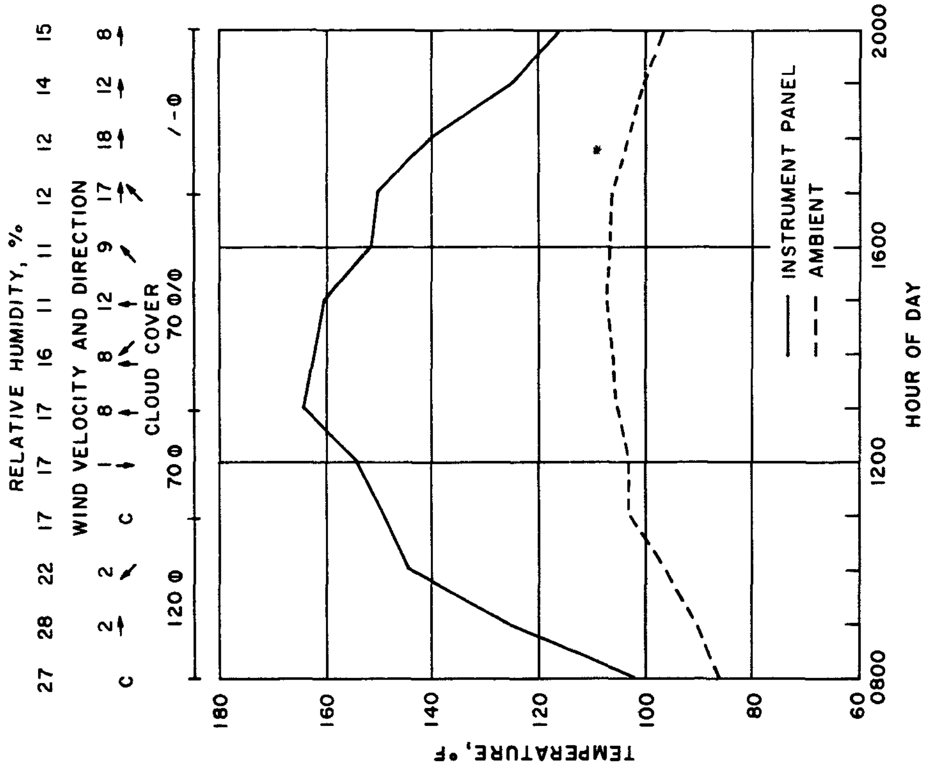

FIG. 22. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 12 August 1960, the Ninth Day in Order of Extreme Temperatures at NOTS.

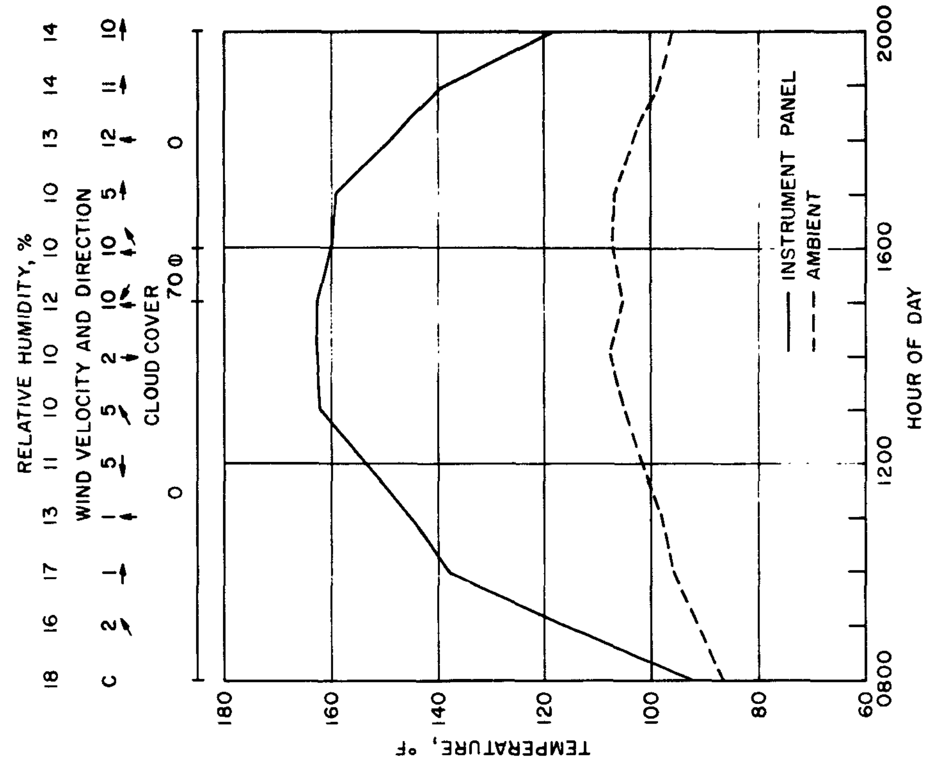

FIG. 23. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 7 August 1960, the Tenth Day in Order of Extreme Temperatures at NOTS.

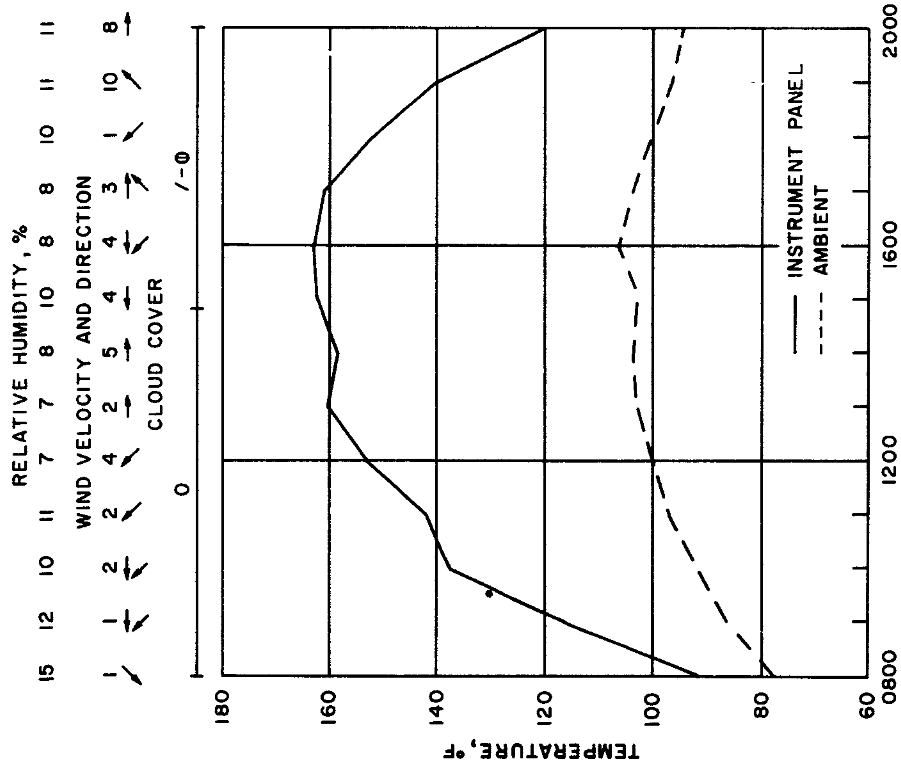

FIG. 24. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 6 August 1960, the Eleventh Day in Order of Extreme Temperatures at NOTS.

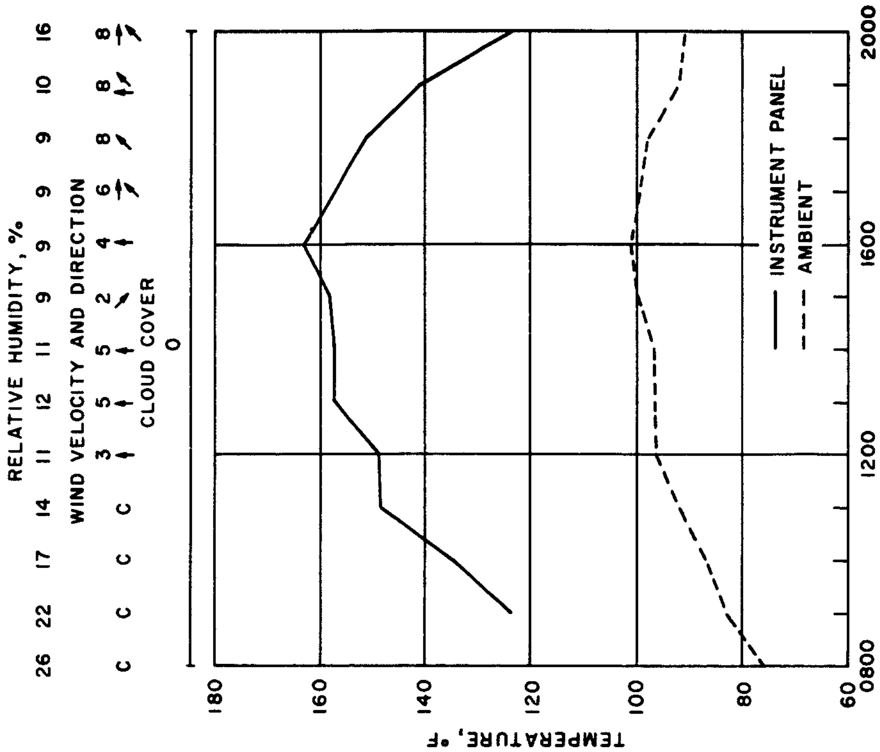

FIG. 25. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 13 July 1960, the Twelfth Day in Order of Extreme Temperatures at NOTS.

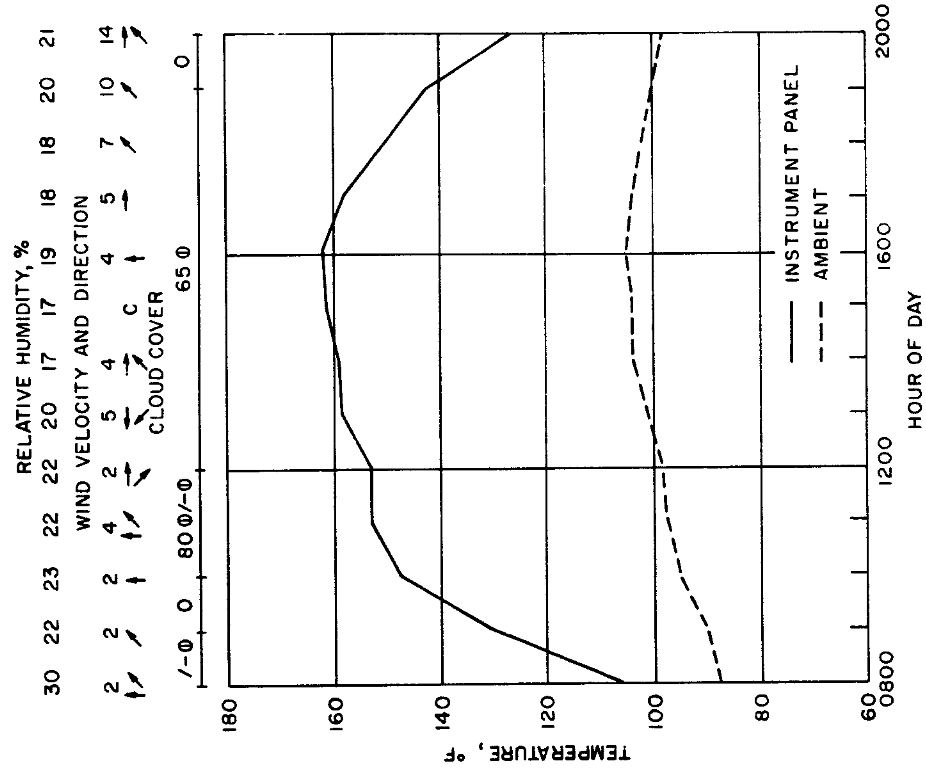

FIG. 26. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 11 August 1960, the Thirteenth Day in Order of Extreme Temperatures at NOTS.

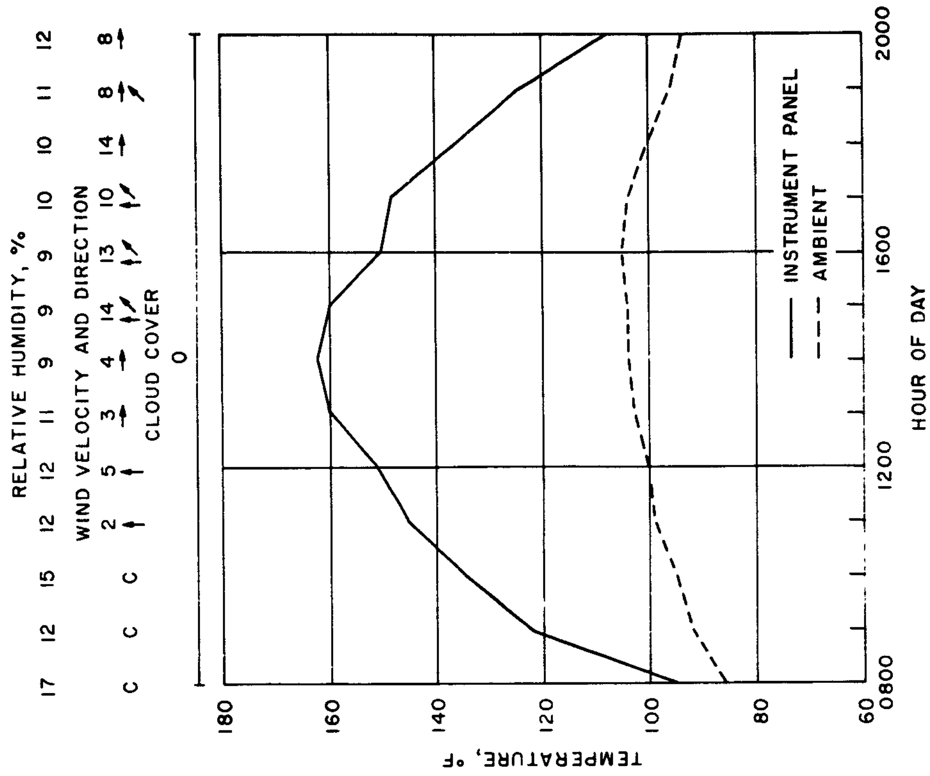

FIG. 27. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 20 August 1960, the Fourteenth Day in Order of Extreme Temperatures at NOTS.

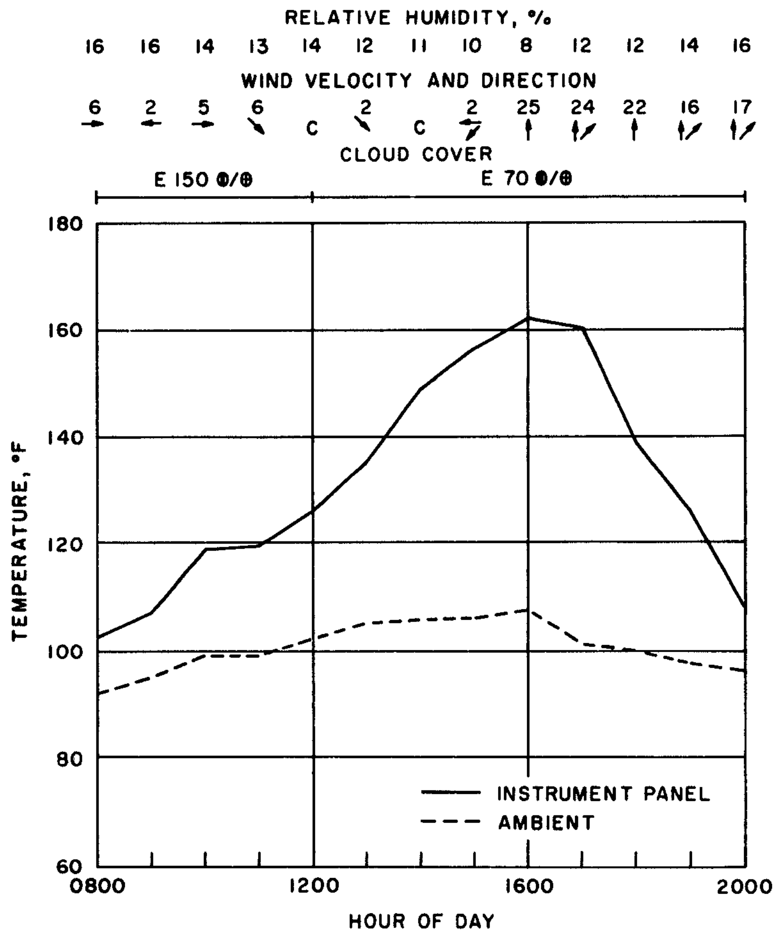

FIG. 28. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 20 July 1960, the Fifteenth Day in Order of Extreme Temperatures at NOTS.

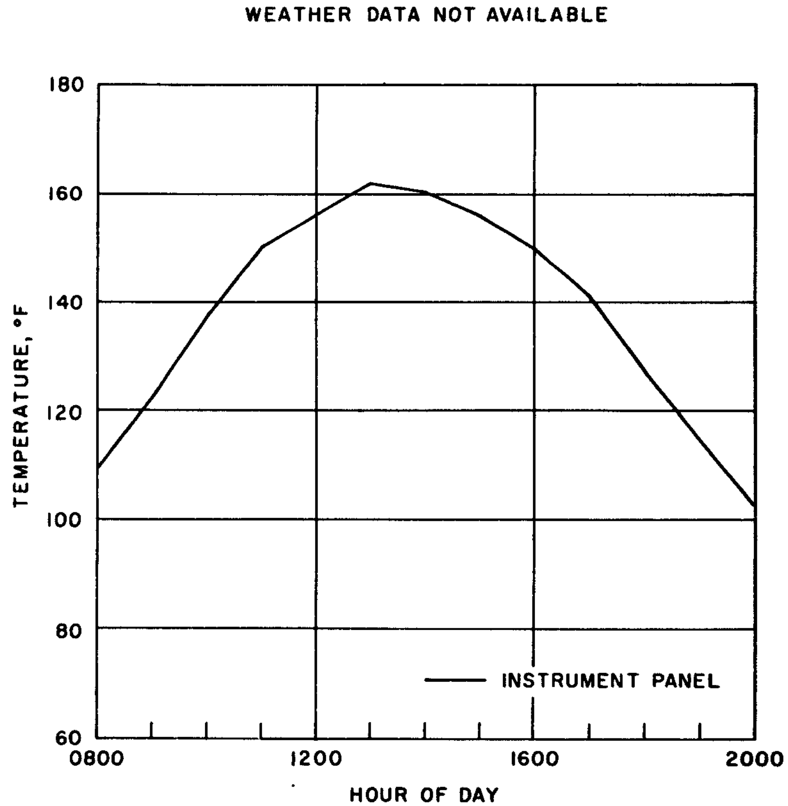

FIG. 29. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 13 August 1960, the Sixteenth Day in Order of Extreme Temperatures at El Centro.

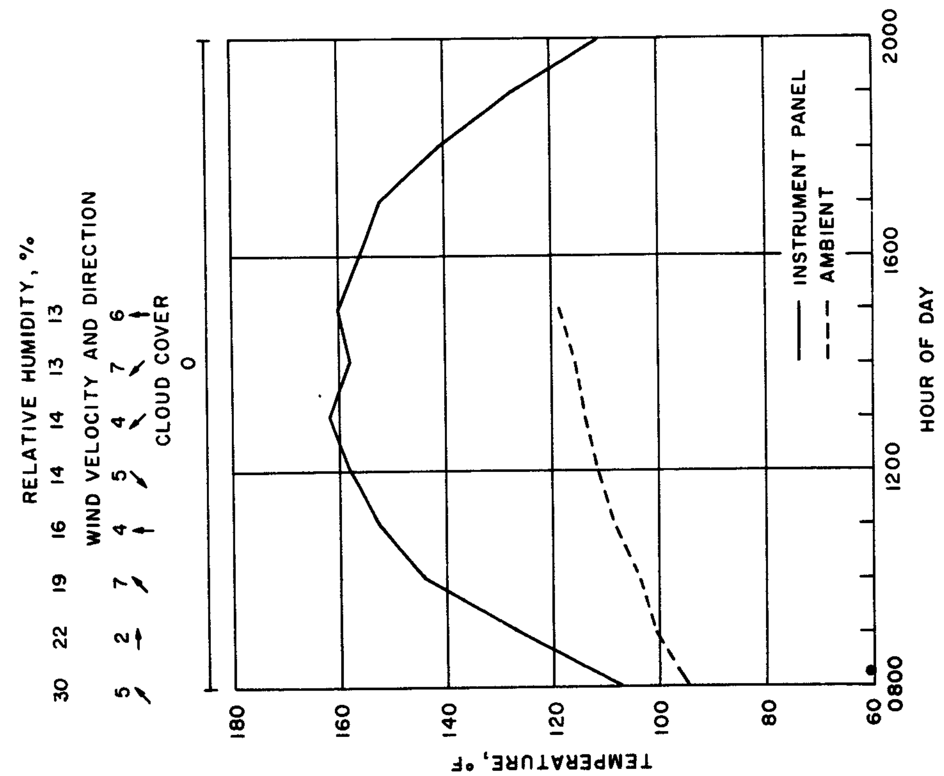

FIG. 30. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 18 August 1960, the Seventeenth Day in Order of Extreme Temperatures at El Centro.

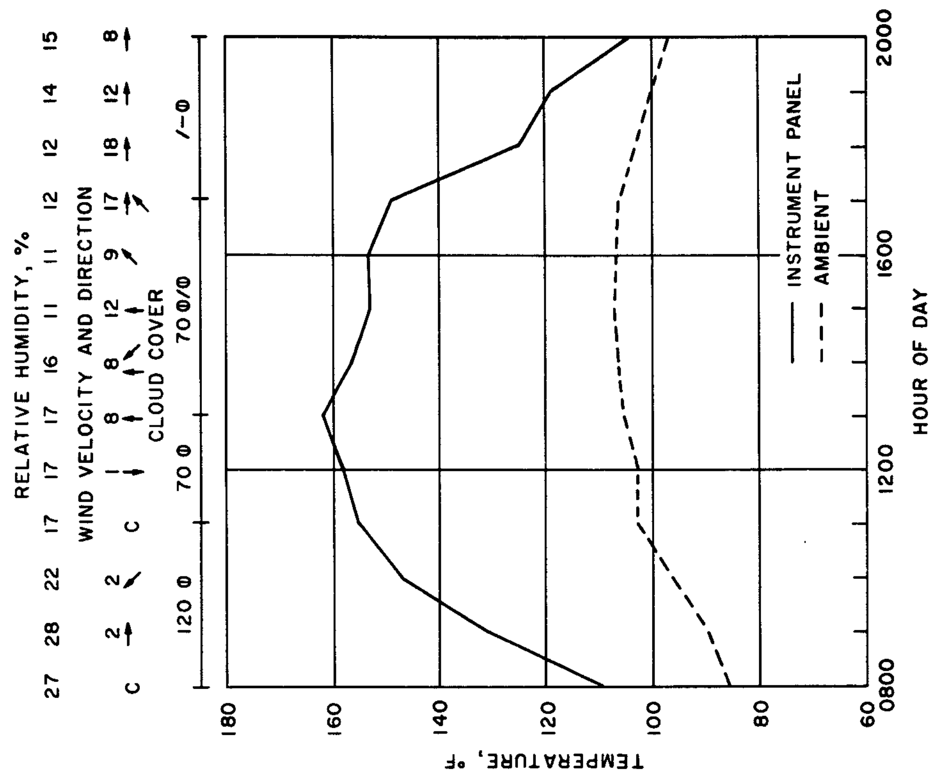

FIG. 31. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 12 August 1960, the Eighteenth Day in Order of Extreme Temperatures at NOTS.

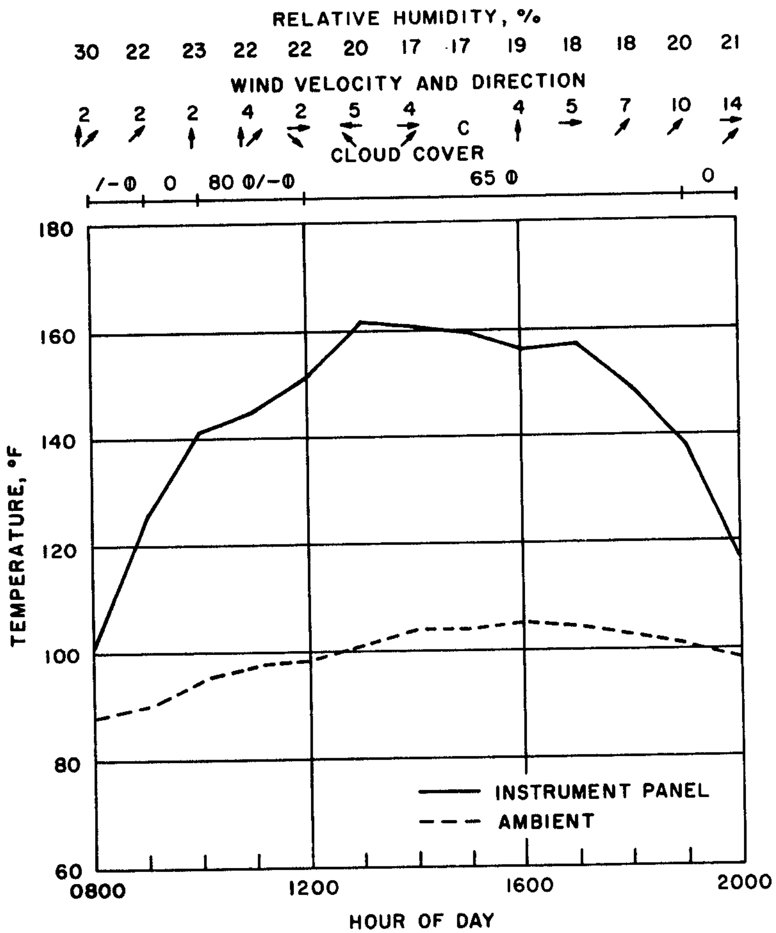

FIG. 32. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 11 August 1960, the Nineteenth Day in Order of Extreme Temperatures at NOTS.

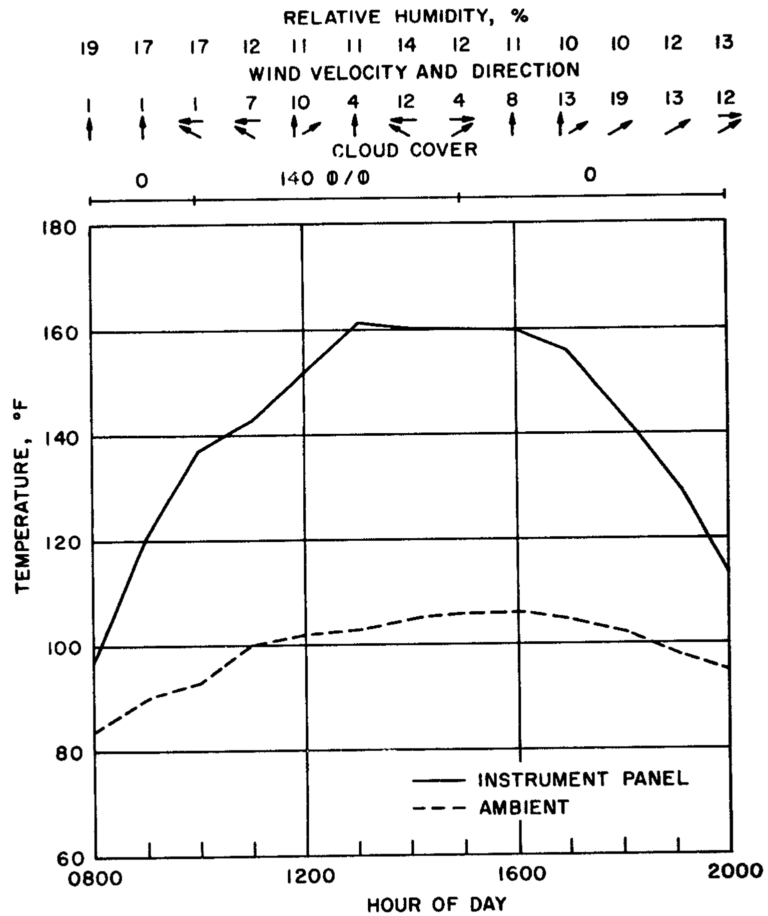

FIG. 33. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 8 August 1960, the Twentieth Day in Order of Extreme Temperatures at NOTS.

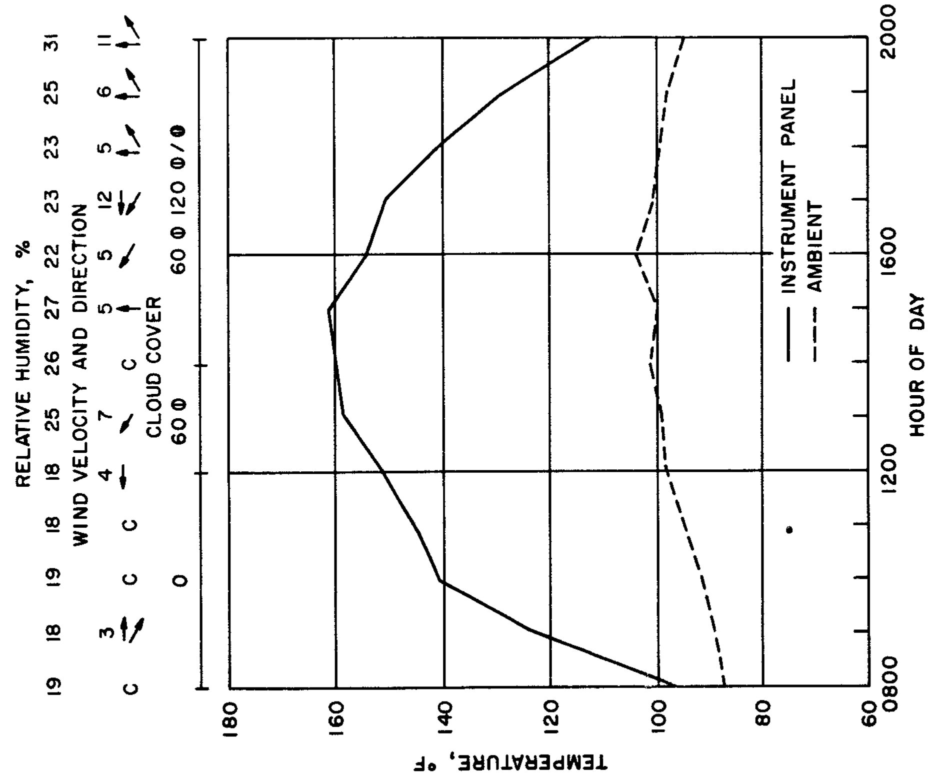

FIG. 34. Maximum Hourly Temperatures Recorded on F-84 Instrument Panel on 11 August 1960, the Twenty-First Day in Order of Extreme Temperatures at NOTS.

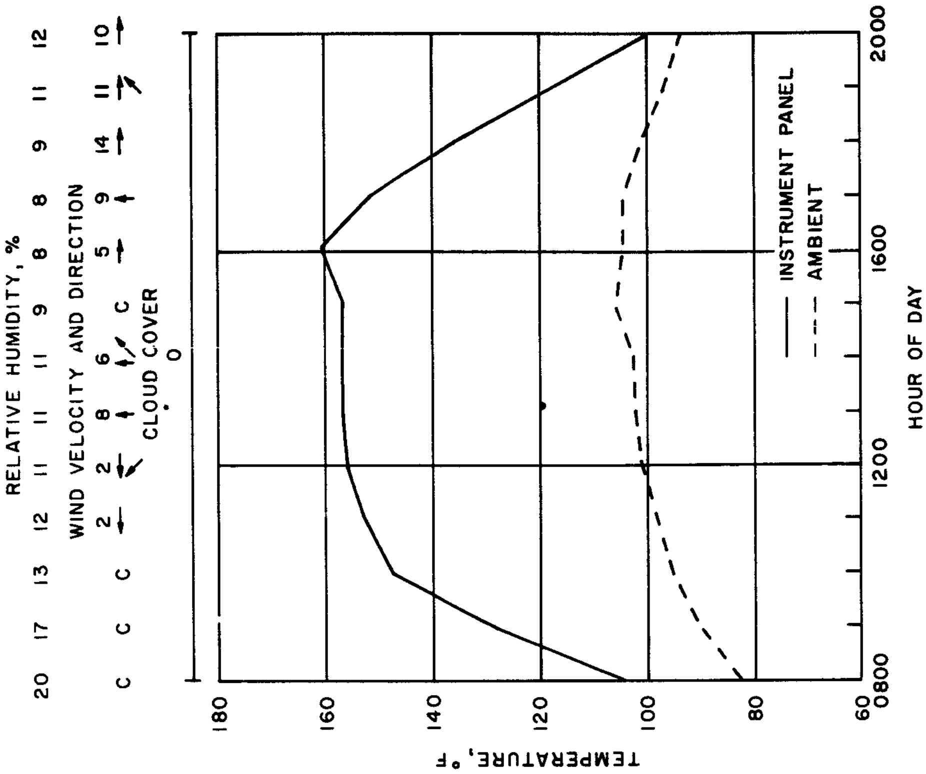

FIG. 35. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 19 August 1960, the Twenty-Second Day in Order of Extreme Temperatures at NOTS.

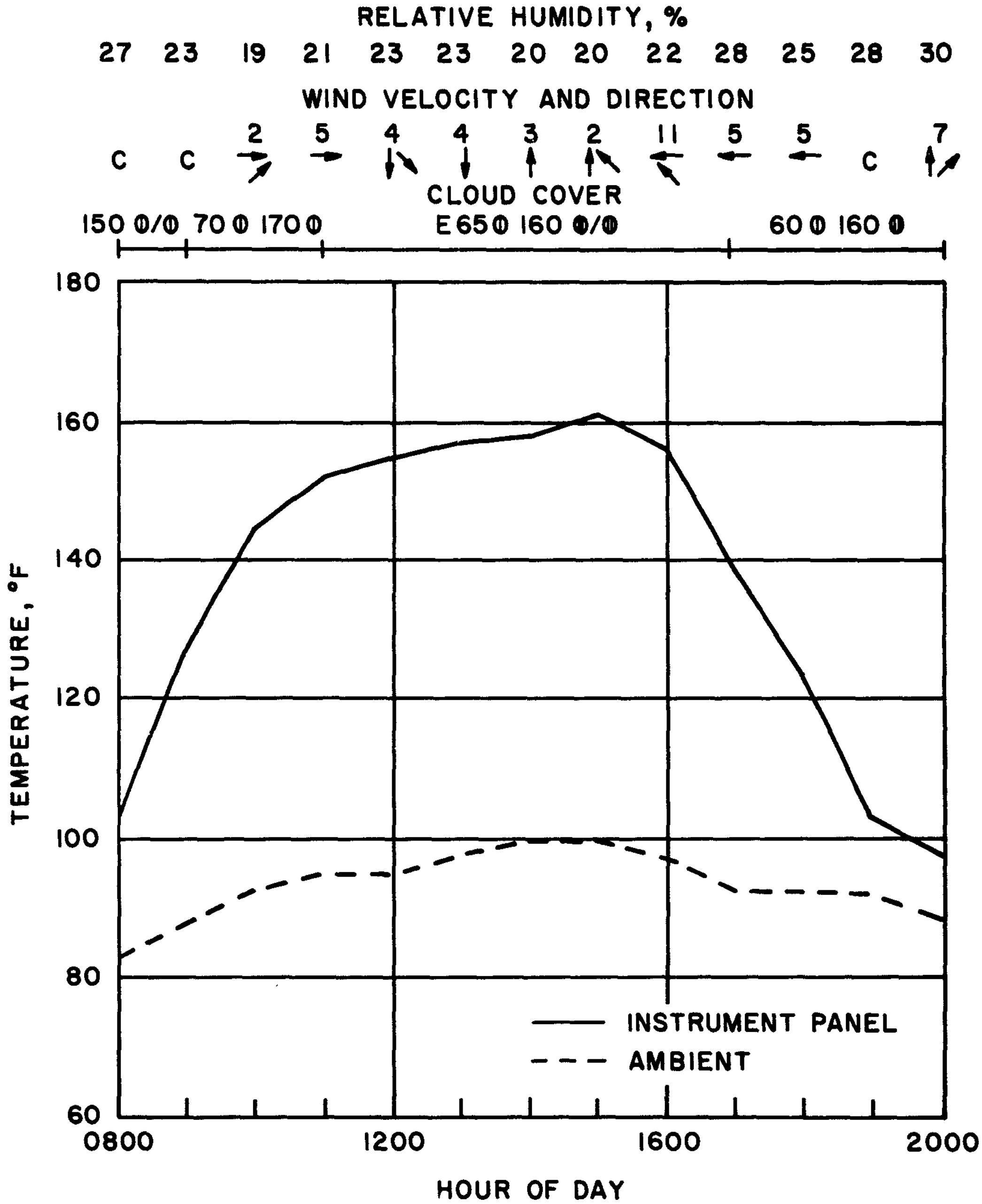

FIG. 36. Maximum Hourly Temperatures Recorded on A4D Instrument Panel on 9 September 1960, the Twenty-Third Day in Order of Extreme Temperatures at NOTS.

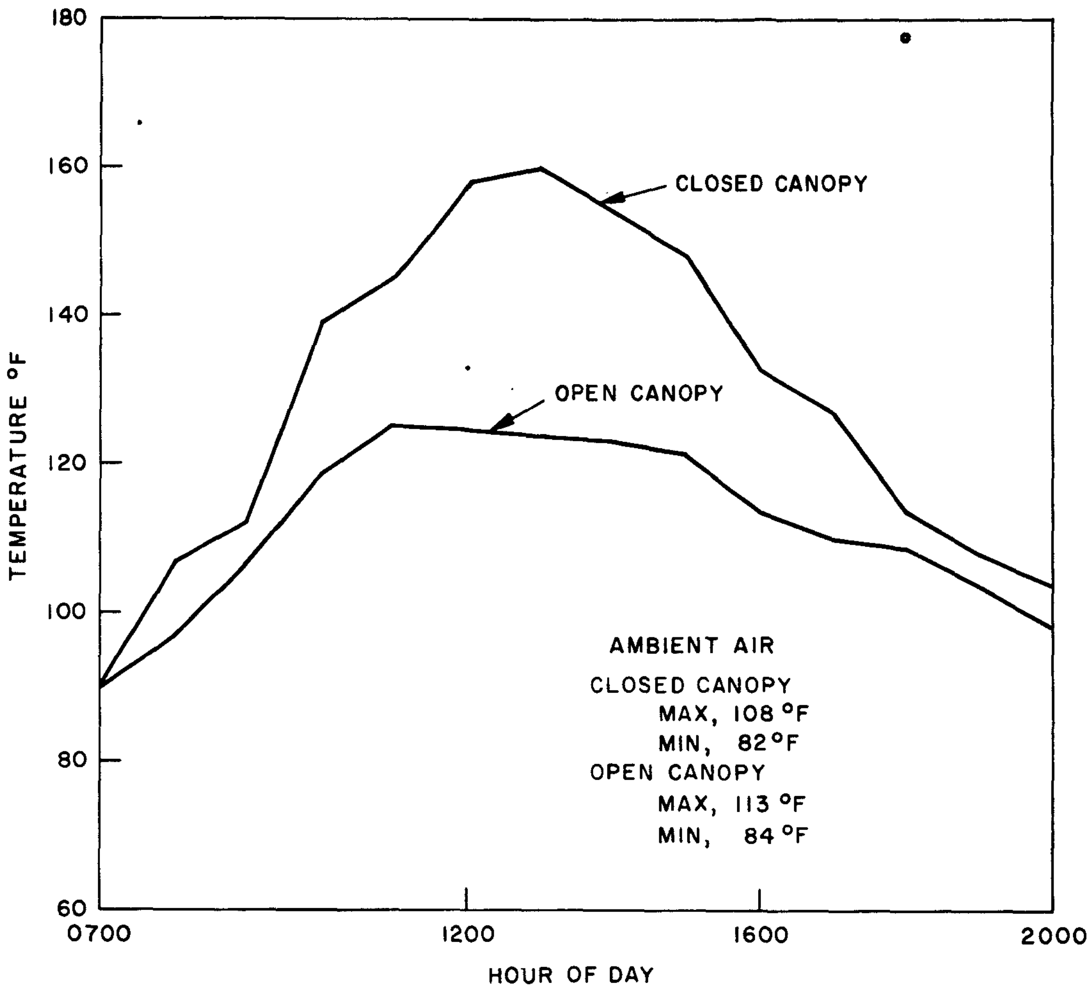

FIG. 37. Difference in Temperature Between Open and Closed Cockpit on B-47E Aircraft at Yuma, Ariz. (Courtesy Frankford Arsenal.)

to which inboard aircraft instruments would be subjected during in-service use.

Figure 38 shows the integrated time at soak temperatures to which the instrument panel of the F-84 aircraft was exposed. The total hours at 168, 165, 160, 155, 150, and 140°F were summed and a curve drawn through the plotted points. The worst case conditions afforded 43.3 hours above 160°F in 15 cycles. The average length of soak during the cycle was about 3 hours.

Figure 39 shows the worst thermal gradients that were recorded at NOTS and NPF during the test series. It can be seen that the worst exposure was at the top of the canopy. The figure shows the maximum temperature lines and gives a composite of the cockpit temperatures for the two summer test sites. The 7 days of maximum cockpit temperatures represent the five highest from NOTS and the two highest from

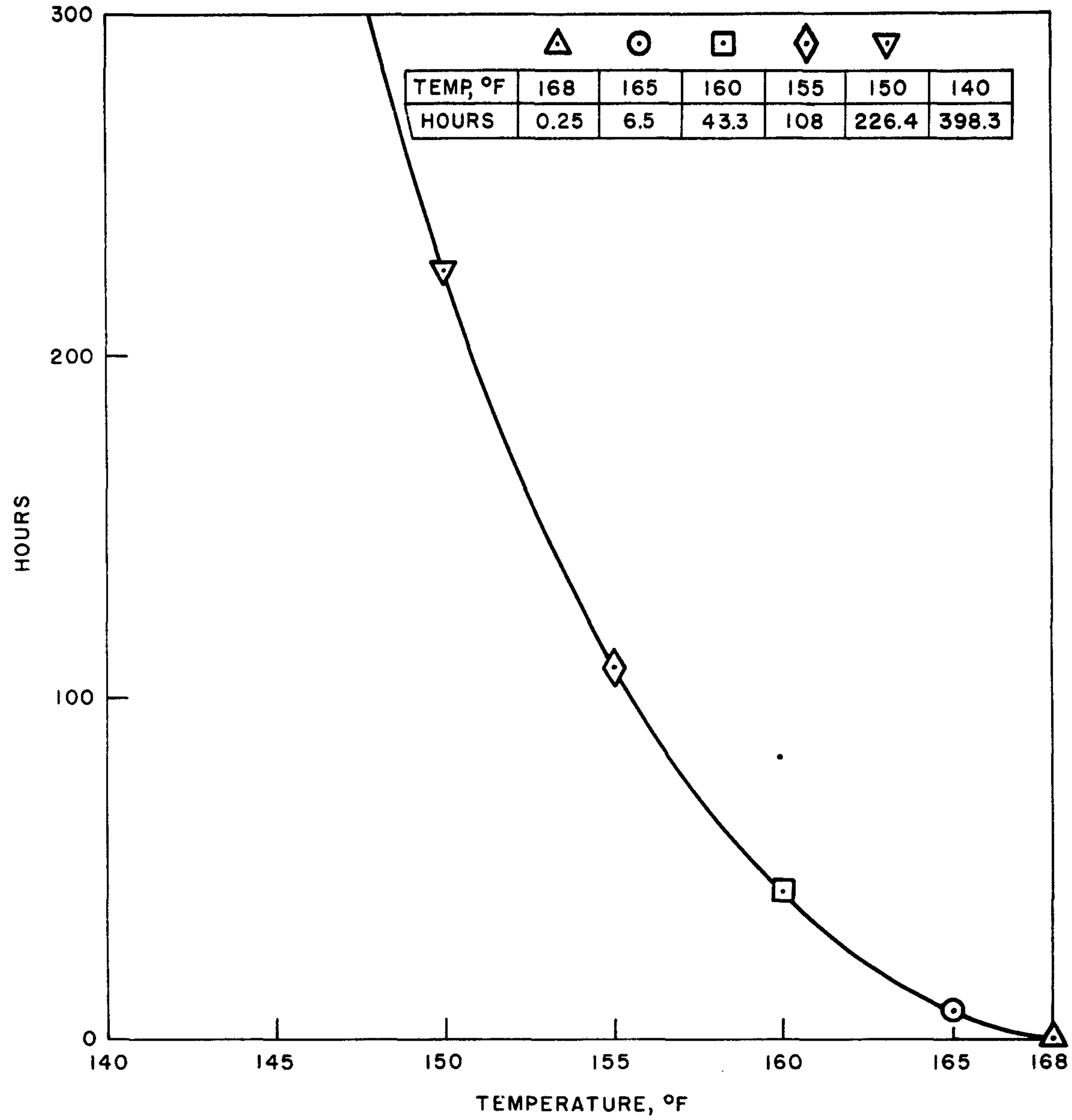

FIG. 38. Integrated Soak Time on Instrument Panel, F-84 Test Vehicle.

NPF. The two curves average the plotted points that were the maximum temperatures recorded in the cockpits of the two A4D test vehicles. It is readily seen that the south-pointed A4D test vehicles exhibited higher over-all cockpit temperatures than the north-pointed F-84 aircraft, although instrument panel temperatures were higher in the F-84 aircraft.

The "hook" in the bottom of the NPF curve is the result of reflected radiation from the concrete hard stand on which the aircraft was parked

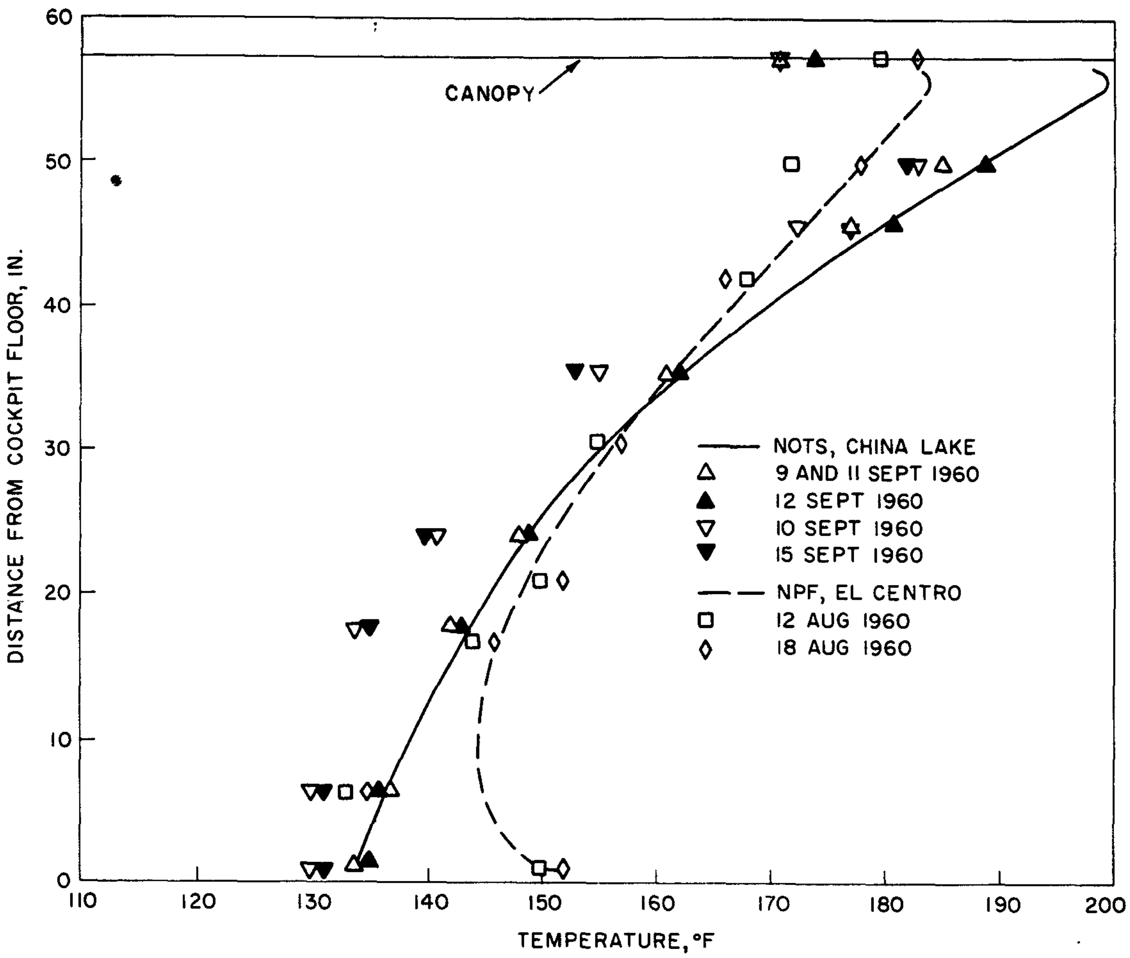

FIG. 39. Worst Thermal Gradients Recorded in Cockpits of Test Vehicles at NOTS and NPF during Test Series.

(see Fig. 3). The curve for the test vehicle at NOTS does not reflect this hook because the underside of this test vehicle was shielded from reflected radiation by mounting timbers (see Fig. 2). An in-service aircraft, of course, would be subjected to this extra thermal driving force. Any instrumentation mounted in the lower one-third of the fuselage probably would be exposed to heating because of this reflected radiation.

The worst thermal gradient on the NOTS-based test vehicle exhibits a decrease in temperature of 1.87°F/in. descending from the canopy to the cockpit floor. This would indicate that the vertical placement of an instrument in the cockpit would tend to influence the maximum temperature to which it would be subjected.

Figure 40 shows the air temperature envelope in the cockpit of a B-47E test vehicle exposed at the Army's Desert Test Center at Yuma, Ariz. (During summer 1961, the Air Force conducted environmental

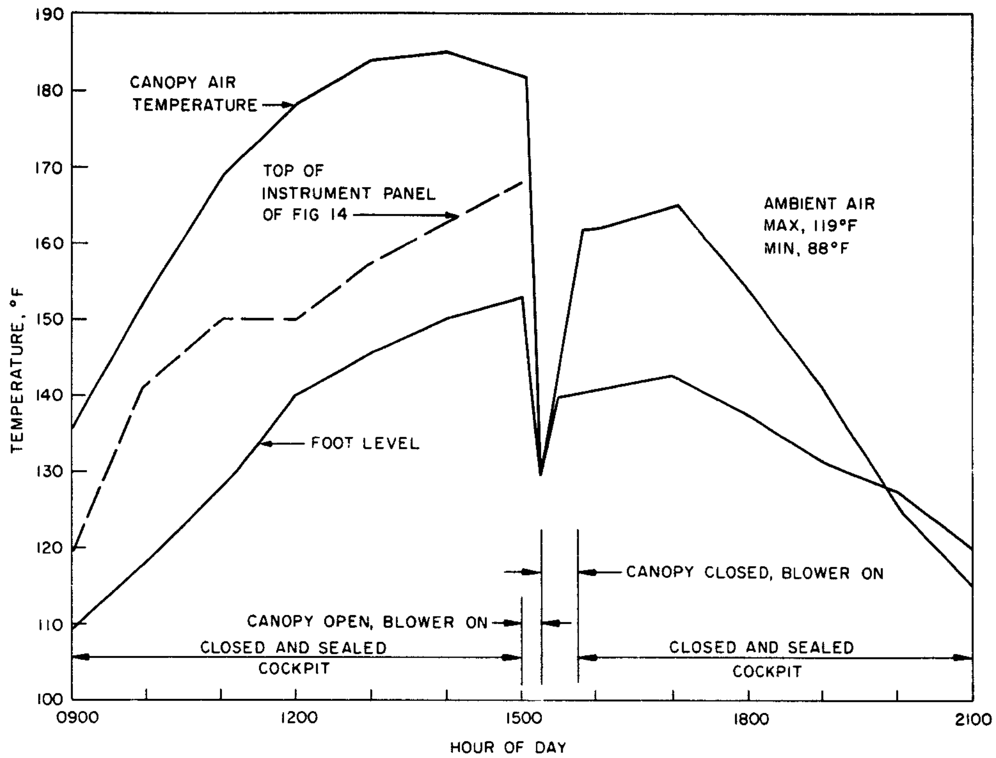

FIG. 40. **Effect of Opening Canopy on B-47E Aircraft at Yuma, Ariz. (Courtesy Frankford Arsenal.)**

tests on aircraft equipment similar to those reported here (Ref. 1). Their test series, conducted at Yuma, resulted in the accumulation of data that agreed to a marked extent with the data obtained by NOTS.) The envelope shows the temperature change that occurred when the aircraft cockpit was sealed and locked from 0900 to 1500 hours, opened from 1500 to 1515 hours, then resealed again from 1545 to 2100 hours. The test sequence was to establish the cockpit air-temperature drop that would occur from opening the canopy. The 15 minutes during which the canopy was open allowed the rapid escape of hot air from the cockpit and the complete collapse of the vertical temperature gradient. With the canopy again closed and sealed, the heat from the cockpit structural members raised the temperature of the instruments, and in about 1 1/4 hours the thermal gradient, as depicted by the envelope, had been re-established to the value it would have had if the cockpit thermal equilibrium had not been disturbed. The dashed line in the figure is taken from the day of maximum temperatures exhibited during the 1960 test series at NOTS on the F-84 aircraft (Fig. 14). Though the placement of this instrument panel temperature line is not exact for the B-47E, it does give a general idea of where in the cockpit envelope the top of the instrument panel would be. It can be seen that the open canopy condition would exhibit the lowest possible thermal demands on aircraft instruments in a non-

operating aircraft. (The B-47E has a full "greenhouse" canopy, similar to the F-84 canopy, but with over twice the square inches of exposed area for solar radiation to penetrate.)

WINTER

The 3 days of minimum cockpit temperatures (27–29 December) were analyzed to show details on extreme environmental conditions that might be present in the cockpit of an aircraft when parked out of doors in an arctic region during the winter. These temperatures are given in Table 2. It can be seen that there is little difference in temperature from the top to the bottom of the cockpit area of the aircraft. During the 3-day interval, the differential temperature throughout the aircraft was 5°F or less. In most instances, the lowest temperature recorded was from a thermocouple placed near the inside surface of the canopy (No. 8 thermocouple in Fig. 7). The highest temperature recorded usually was from a thermocouple placed on the rocket catapult unit behind the pilot's ejection seat. The exposed-to-radiation thermocouple was reporting a loss of radiant energy to the upper atmosphere from the cockpit through

TABLE 2. COCKPIT TEMPERATURES RECORDED DURING LOWEST TEMPERATURE PERIOD OF TEST SERIES

All temperatures are °F.

Hour	27 December			28 December			29 December			30 December		
	High	Low	Amb.	High	Low	Amb.	High	Low	Amb.	High	Low	Amb.
0100	-53	-58	-53	-61	-65	-63	-60	-62	-59	-53	-61	-46
0200	-53	-58	-55	-61	-65	-63	-60	-62	-58	-48	-58	-42
0300	-53	-56	-53	-62	-65	-61	-59	-61	-59	-45	-56	-38
0400	-52	-55	-53	-63	-65	-65	-60	-62	-61	-40	-50	-35
0500	-51	-54	-52	-62	-66	-63	-61	-64	-63	-36	-47	-31
0600	-52	-53	-52	-60	-64	-62	-61	-63	-61	-33	-45	-28
0700	-52	-53	-52	-60	-64	-62	-60	-64	-62	-28	-40	-22
0800	-52	-53	-52	-62	-65	-63	-61	-65	-63	-24	-36	-18
0900	-52	-53	-52	-61	-65	-63	-62	-65	-62	-21	-32	-18
1000	-52	-53	-51	-62	-66	-66	-62	-66	-63	-22	-30	-18
1100	-53	-54	-55	-62	-66	-63	-61	-66	-62	-20	-28	-17
1200	-52	-55	-54	-61	-65	-64	-62	-65	-60	....	....	....
1300	-53	-56	-56	-62	-65	-64	-62	-65	-60	....	....	....
1400	-54	-58	-58	-61	-65	-64	-63	-65	-64	....	....	....
1500	-55	-58	-59	-61	-66	-63	-60	-65	-61	....	....	....
1600	-56	-59	-60	-62	-66	-63	-60	-65	-65	....	....	....
1700	-57	-59	-60	-63	-66	-63	-60	-65	-64	....	....	....
1800	-57	-61	-62	-63	-66	-63	-61	-66	-62	....	....	....
1900	-58	-61	-62	-64	-66	-63	-60	-65	-62	....	....	....
2000	-59	-62	-63	-64	-66	-64	-61	-65	-61	....	....	....
2100	-59	-62	-64	-62	-63	-60	-60	-64	-62	....	....	....
2200	-60	-64	-64	-60	-63	-59	-60	-64	-59	....	....	....
2300	-61	-65	-64	-61	-63	-59	-59	-64	-60	....	....	....
2400	-61	-65	-63	-60	-62	-58	-59	-63	-59	....	....	....

the canopy. This would explain how the minimum cockpit temperature was lower than the outside air temperature as recorded at the Stevenson shelter. (In some cases, the differential temperature between the standard outside air temperature and the temperature at thermocouple No. 8 was as much as 5°F.) The rocket catapult, on the other hand, is relatively shielded from rapid changes if little thermal driving force is present. Behind the cockpit bulkhead there is a large fuel cell; in front of the catapult are the Martin-Baker seat, parachute pack, and survival gear; on each side and bottom is aircraft skin.

On 28 and 29 December 1961, the lowest temperatures of the test series were recorded. The cockpit temperature descended to -66°F on both days. The longest exposure at this temperature was 6 hours on 28 December 1961. These were the only times during the test that the Navy's minimum qualification temperature (-65°F) was exceeded.

It became quite evident that even a small layer of snow would reduce radically the cockpit gradient. Once the canopy was insulated by the precipitation, the thermocouples indicated a trend toward a single temperature, which for all practical purposes was the outside air temperature as recorded at the Stevenson shelter.

Daily Record of Minimum Temperatures. The comprehensive results of this program can be seen in Fig. 41 and Table 3. The correlation

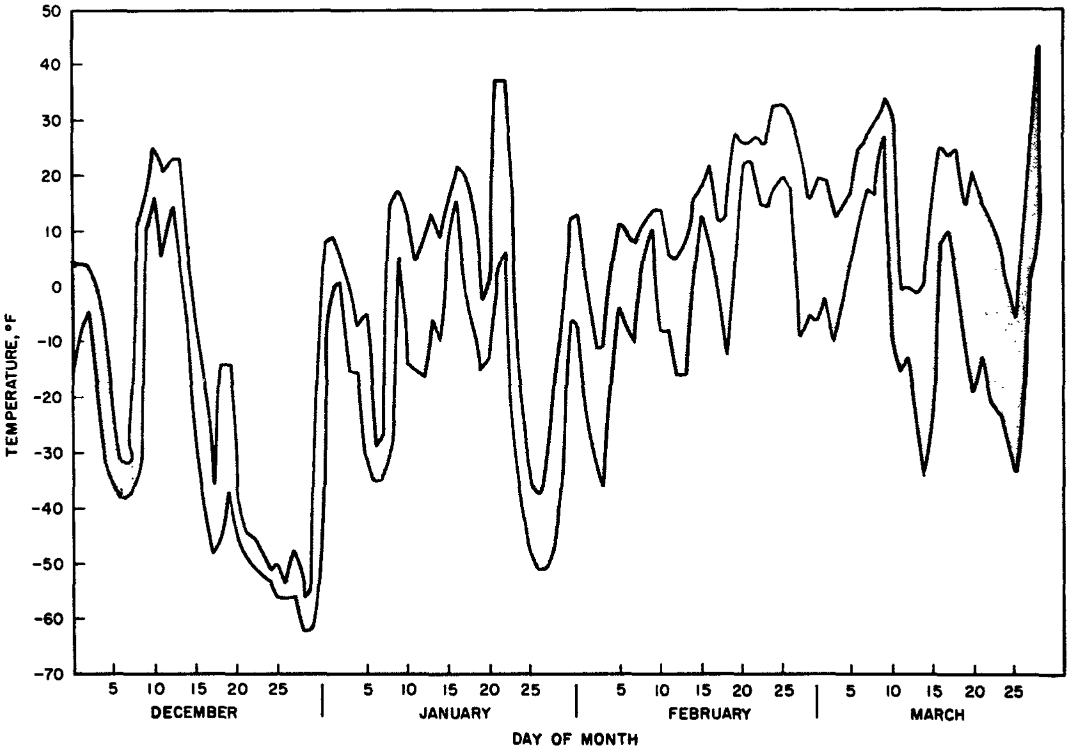

FIG. 41. Daily High—Low Temperature Envelope Recorded During Winter 1961—1962.

TABLE 3. DAILY HIGH–LOW TEMPERATURES RECORDED DURING WINTER 1961–62

All temperatures are °F.

Day	December 1961		January 1962		February 1962		March 1962	
	High	Low	High	Low	High	Low	High	Low
1	5	-16	9	0	-2	-25	20	-6
2	4	-7	3	1	-11	-28	19	2
3	4	-4	0	-15	-11	-36	12	-10
4	1	-19	-8	-15	3	-15	12	-7
5	-24	-32	-5	-30	12	-2	15	-7
6	-31	-36	-30	-35	9	-7	25	11
7	-32	-38	-26	-35	8	-10	27	18
8	11	-30	15	-30	12	6	30	17
9	24	13	17	6	14	11	34	30
10	25	17	14	-14	14	-8	31	-10
11	21	6	5	-15	6	-8	-10	-15
12	23	15	7	-16	5	-16	0	-13
13	23	8	13	-5	8	-16	-1	-22
14	5	-7	8	-10	16	3	1	-34
15	-7	-28	17	7	18	14	18	-23
16	-15	-40	22	17	22	8	25	8
17	-39	-48	21	3	12	-2	24	10
18	-14	-46	15	-7	13	-12	25	0
19	-14	-37	-3	-15	28	4	15	-13
20	-37	-45	1	-13	26	22	21	-19
21	-45	-48	37	3	26	23	15	-13
22	-45	-50	37	6	27	15	12	-21
23	-48	-52	7	-28	25	15	13	-22
24	-51	-53	-23	-40	33	19	1	-26
25	-50	-56	-36	-48	33	20	5	-33
26	-54	-56	-37	-51	31	18	....	....
27	-48	-56	-33	-51	24	-1	....	....
28	-56	-62	-15	-47	16	-5	43	16
29	-55	-62	-4	-32	....	....	....	....
30	-15	-53	12	-6	....	....	....	....
31	8	-17	....	....	....	....	....	....

between low ambient air temperatures as reported by the Weather Bureau and the expected low temperatures to which an exposed, arctic-based aircraft would be subjected is excellent. Figure 41 is a plot of the maximum and minimum standard air temperatures as reported at the Fairbanks Weather Bureau Station located about 5 miles from the test site at Fairbanks International Airport. As can be seen, the cold snaps are irregular. The usual Alaskan cold snap will run anywhere from 3 to 9 days. Table 4 is a tabulation of maximum and minimum temperatures recorded during winter 1960-61. The trends are similar to those of winter 1961-62, though the actual temperatures are quite different when the two winter seasons are compared. It can be seen that the coldest days in winter 1960-61 were -38°F, while in winter 1961-62 the official Weather Bureau low was -62°F, the coldest since 1937, according to the Fairbanks Weather Station records.

TABLE 4. DAILY HIGH–LOW TEMPERATURES RECORDED DURING WINTER 1960–61 FOR COMPARISON WITH TEMPERATURES RECORDED DURING WINTER 1961–62

All temperatures are °F.

	November 1960		December 1960		January 1961		February 1961		March 1961	
Day	High	Low	High	Low	High	Low	High	Low	High	Low
1	29	17	8	–18	10	–15	2	–27	0	–17
2	27	15	–4	–23	15	1	–9	–32	–3	–31
3	38	14	–3	–22	2	–20	5	–15	0	–38
4	32	14	–1	–25	–16	–26	21	–4	8	–30
5	22	10	6	–11	–8	–26	19	–4	10	–29
6	17	2	15	–9	1	–9	5	–5	12	–28
7	29	4	39	12	0	–26	15	–7	15	–27
8	27	12	38	16	–5	–34	7	–7	15	–29
9	22	8	42	28	–9	–29	8	–5	15	–29
10	16	–3	35	4	–14	–28	1	–20	1	–28
11	9	–3	12	–5	–3	–20	5	–20	4	–10
12	11	2	16	–9	1	–9	3	–9	0	–19
13	7	–9	34	–9	–4	–24	0	–7	–8	–31
14	8	1	33	9	–15	–26	4	–14	–8	–38
15	8	–3	10	–9	–10	–26	8	–10	–10	–31
16	7	–12	10	–10	–18	–27	9	–20	–5	–29
17	15	–6	2	–13	–4	–28	1	–31	5	–31
18	8	2	9	–18	13	–5	9	–20	23	–9
19	7	–16	10	–23	34	10	3	–20	29	5
20	–14	–33	5	–14	45	10	15	–26	21	–4
21	–16	–34	12	–8	47	26	12	–25	17	–2
22	–11	–22	5	–4	33	17	10	–27	25	–4
23	–18	–31	14	–4	30	7	7	–21	29	10
24	–27	–35	19	–2	27	4	–2	–22	28	8
25	–26	–38	20	–6	31	10	6	–25	25	5
26	–13	–32	7	–6	25	–1	17	–5	22	1
27	6	–17	22	–4	25	–5	8	–6	28	–3
28	2	–15	35	13	13	–12	7	–8	30	0
29	–9	–28	20	15	7	–20	.....	....	42	–10
30	1	–33	20	–2	0	–25	....	....	48	28
31	....	....	15	–13	4	–26	....	....	44	28

A comparison of the cockpit area of an aircraft during a heating trend with a fully enclosed, metal section of an aircraft during a heating trend is given in Fig. 42 and 43. The example is drawn from a sequence of days when a rapid warming trend was intermingled with a clear sky condition, an overcast condition, and a precipitation condition.

Note in Fig. 42 how the cockpit envelope is started at a zero vertical thermal gradient and rises in gradient to a maximum of 10°F during the warming trend. Note, also, how the gradient starts to shrink as the warming trend continues and the overcast sky releases snow. The trend of collapse of the gradient continues into 9 December 1961, as the canopy is covered with a blanket of snow 1 1/2 inches deep. The thermal insulation forces the cockpit to attain again a single temperature that closely approximates the standard outside air temperature. It can be

seen from this sequence why it was necessary to sweep the snow from the aircraft after each snow fall to attain minimum temperatures on the aircraft instruments.

The same information was obtained from the nose section of the aircraft, although the vertical thermal gradient was much less than that through the cockpit during this sequence. It is evident that the nose section was "warmer" to start with than the cockpit and continued to exhibit this warmth until the blanket of snow tended to equalize the temperatures at the two locations on the aircraft.

Note from these figures that the outside air temperature line rises evenly during the major warming trend on 8 December 1961. This is in marked contrast to the normal plot of outside air temperature in the arctic as seen in Fig. 41.

Figure 44 shows the trend of outside temperatures and the resulting cockpit temperature envelope during a series of days in the winter test series. On 14 December, the temperature descends from near 0°F, reaching below -50°F on 17 December. This low temperature continues until 18 December, when a rise begins to occur. The temperature levels off during the latter hours of 18 December and begins to descend again on 19 December. Note the fluctuations of the outside air temperature from hour to hour. There are temperature changes of as much as 24°F/hr, as shown between 2400 hours on 17 December and 0100 hours on 18 December. This continuously changing thermal driving force exerts a marked effect on the behavior of cockpit temperatures and the cockpit's vertical thermal gradient. The envelope of the cockpit's temperature continues expanding and contracting until the outside air temperature levels off (17 December) and allows the cockpit temperature to equalize. Note that there are many instances during this example when the outside air temperature is below the lowest cockpit temperature. The converse is also true. A comparison of Fig. 44 with the overall daily high-low temperature envelope as reported at Fairbanks International Airport (Fig. 41) will give a good idea as to the adaptability of these data for prediction of "design minimum temperatures" for various aircraft instruments.

CONCLUSIONS

SUMMER

The summer series of tests established maximum cockpit temperatures and the general gradient of temperature maximums that might be experienced in cockpit areas by Fleet aircraft.

The maximum instrument panel temperature recorded was 168°F. This is slightly above the qualification temperature of 160°F for aircraft instruments, but not enough to cause alarm. The data presented show that even under locked, sealed conditions, the cockpit environment

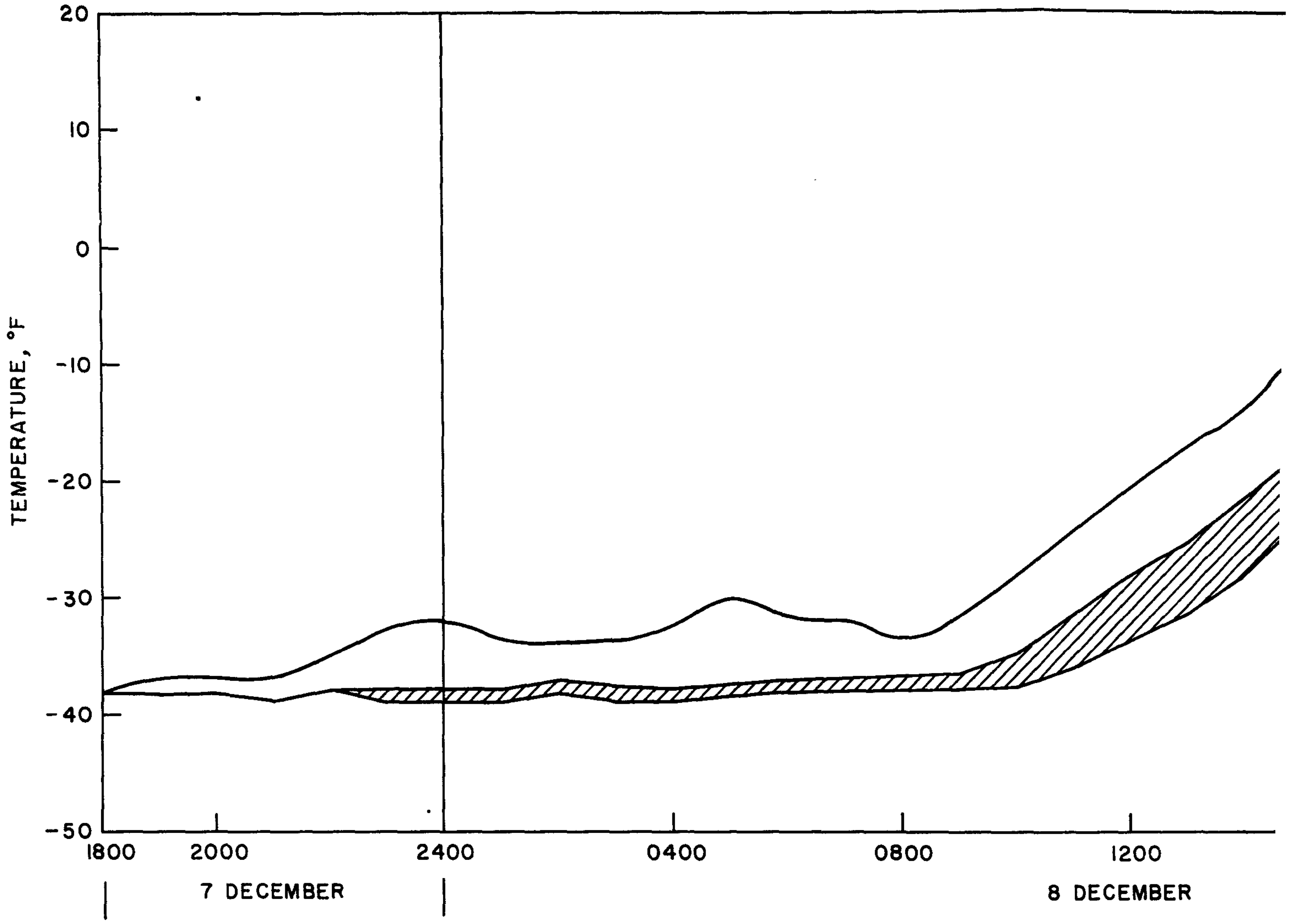

FIG. 42. Temperature Enve

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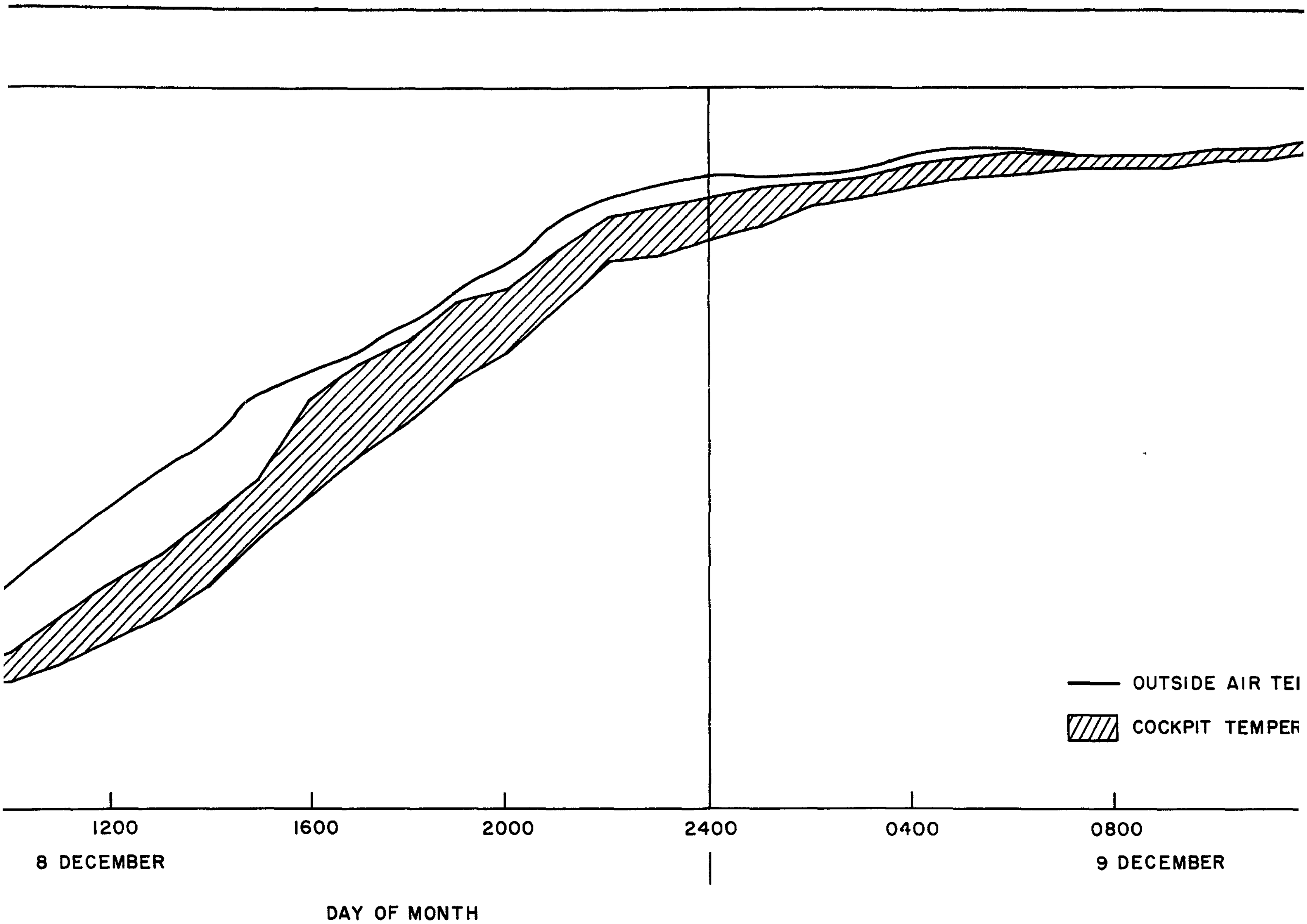
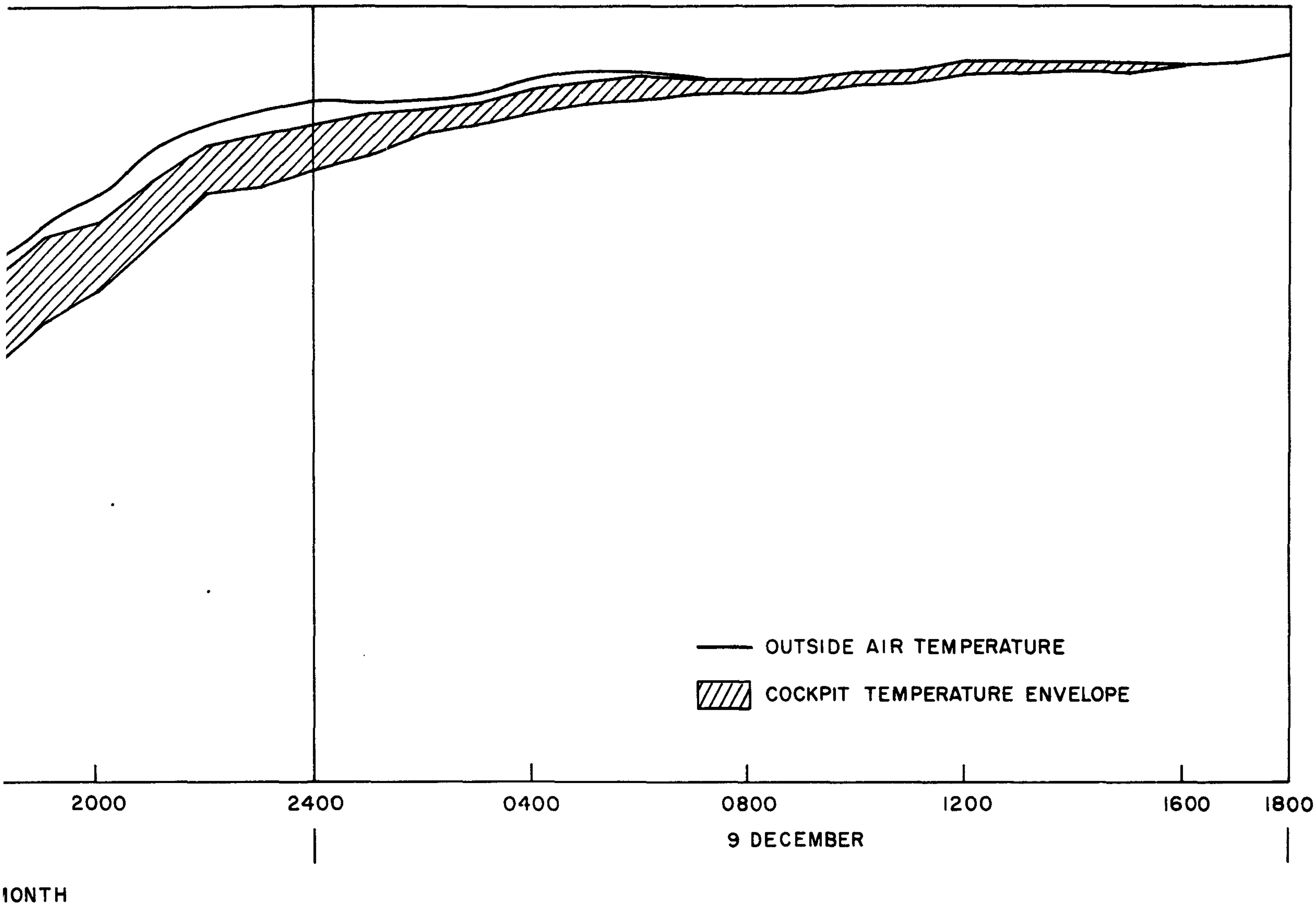


FIG. 42. Temperature Envelope in Cockpit of F9F Aircraft During Heating Trend.



' Aircraft During Heating Trend.

3

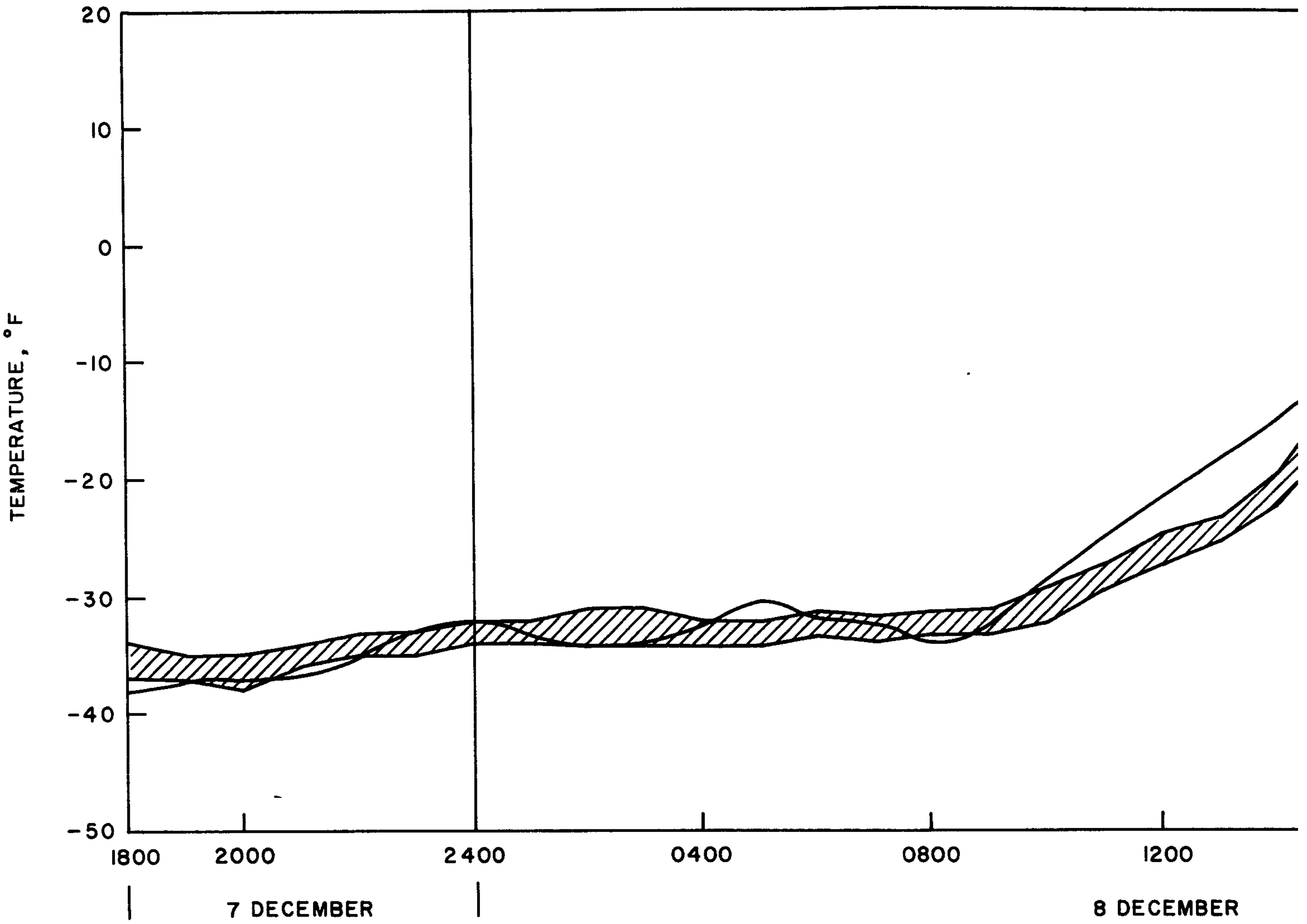


FIG. 43. Temperature E

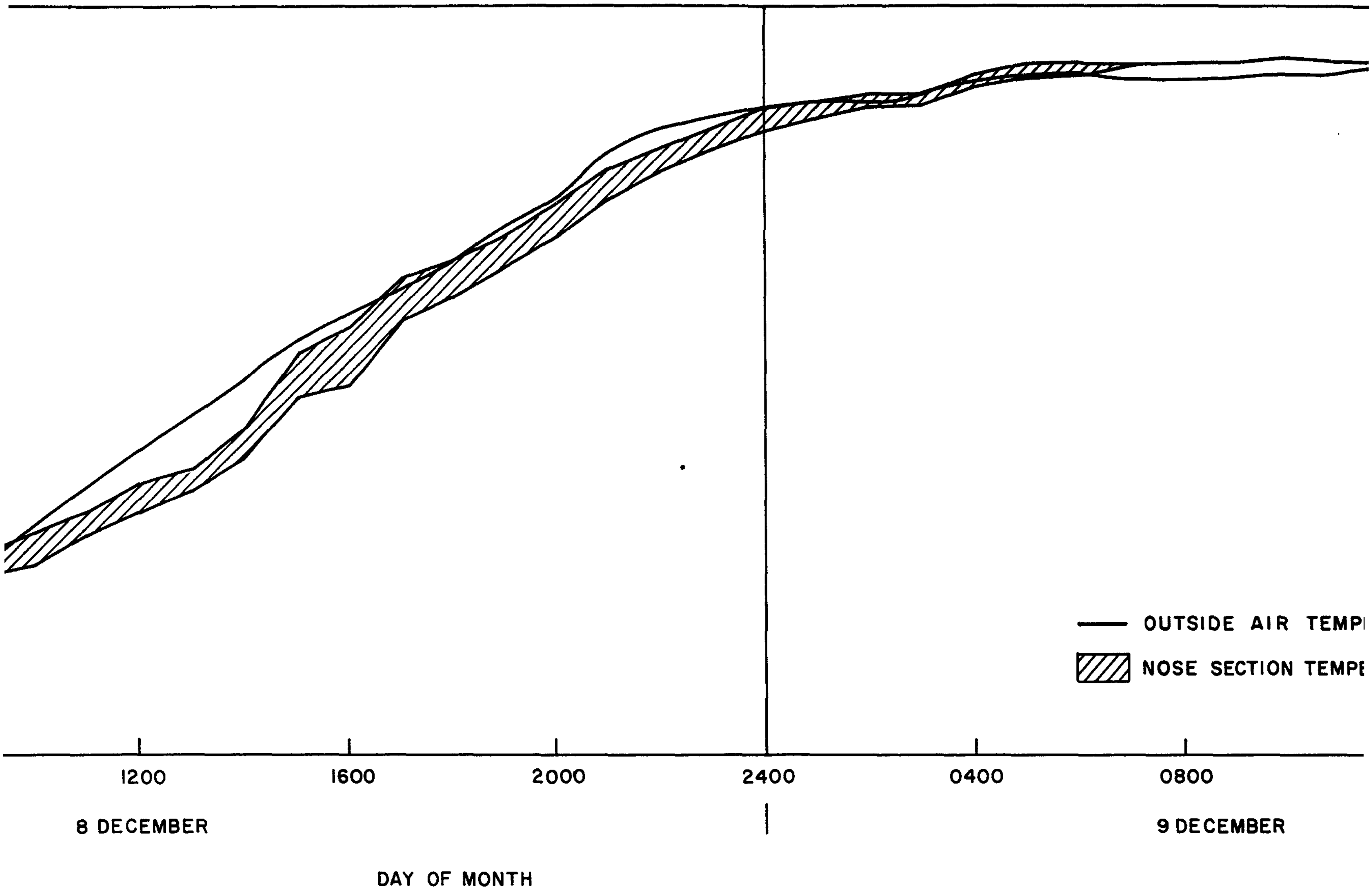
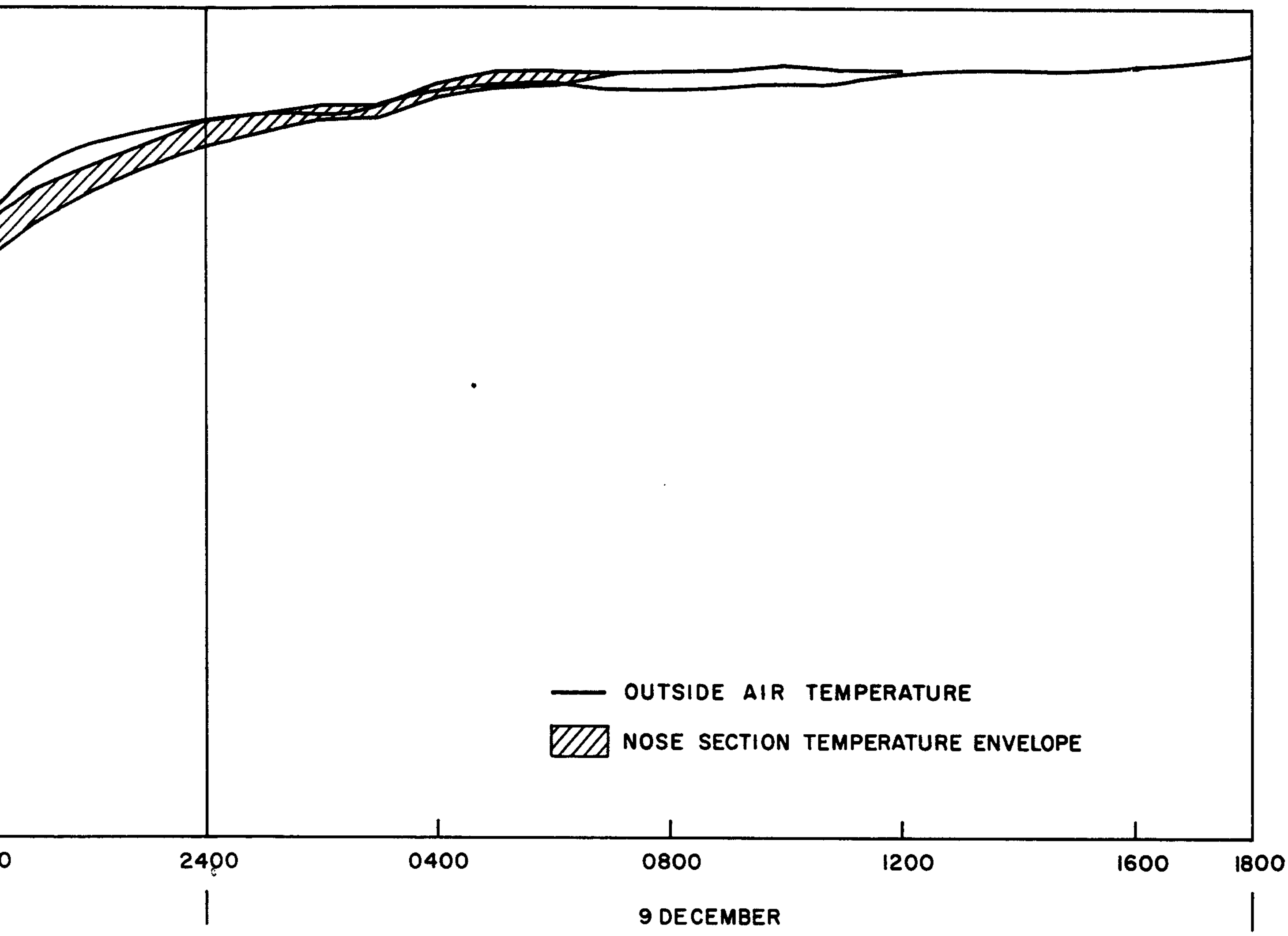


FIG. 43. Temperature Envelope in Nose Section of F9F Aircraft During Heating Trend.

2



aft During Heating Trend.

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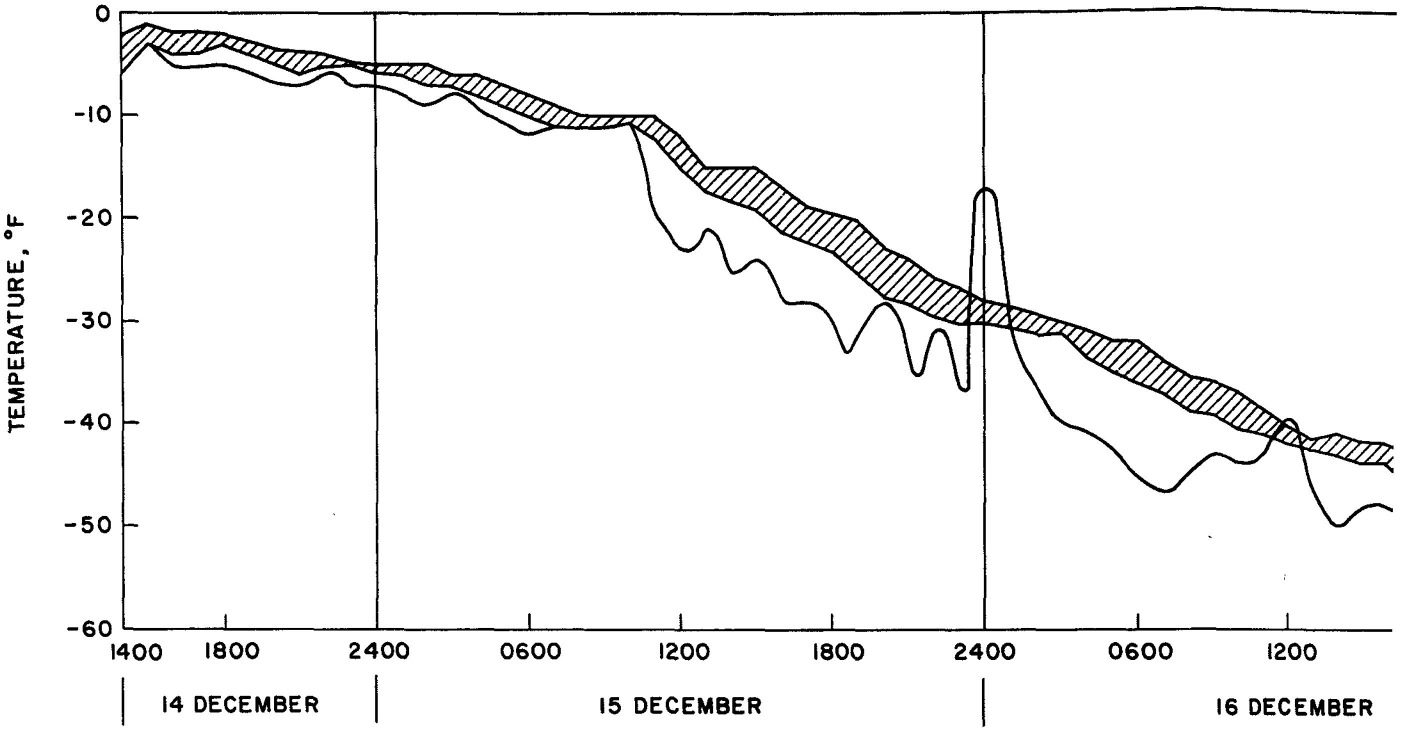
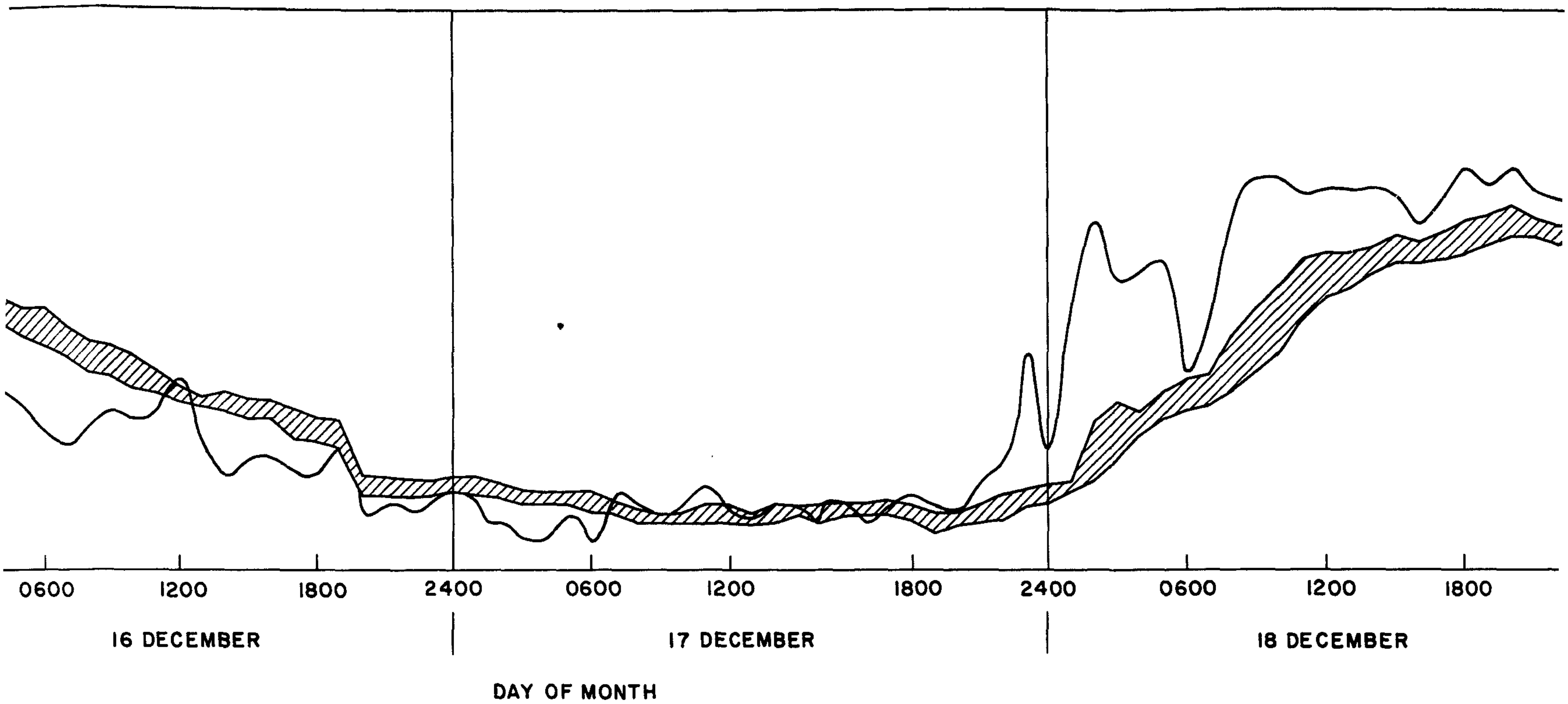


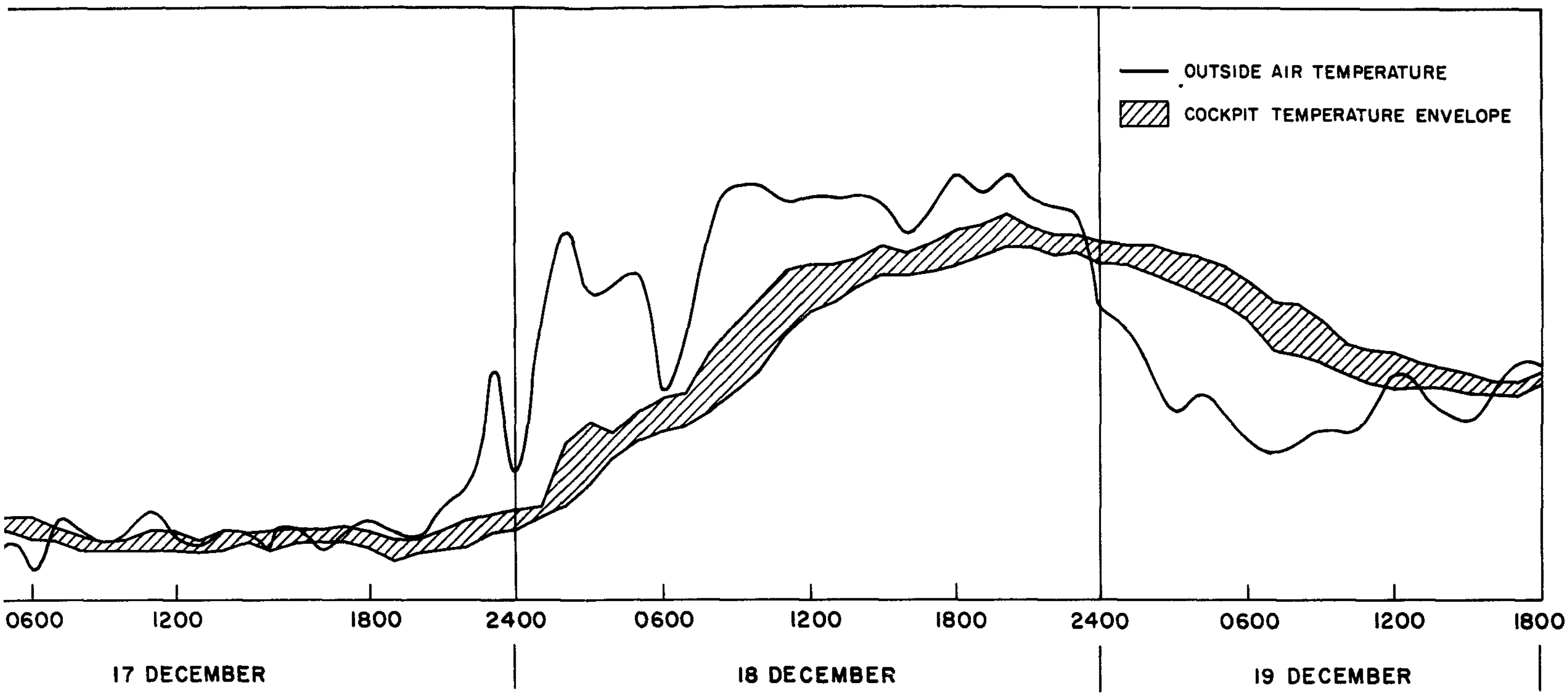
FIG. 44. Trend of Cockpit Temperat

1



Trend of Cockpit Temperature Envelope Compared With Outside Temperature During 6-Day Period During Test Series.

2



F MONTH

Outside Temperature During 6-Day Period During Test Series.

3

is well within the state of the art. Figure 40 shows that actual cockpit instrument environments are much less severe than those indicated in this report. The drop from 182 to 130°F by simply opening the canopy shows that the sealed-cockpit values are much higher than those experienced by in-service aircraft. It would seem that, this being the case, the qualification temperature of 160°F could be lowered to 140°F, if aircraft canopies continue to be left open on desert airfields. The only exception would be the standby compass or other instrumentation mounted directly under the canopy, or in the upper portions of the cockpit. It should be concluded that the lower the non-heat-producing instrument is mounted in the cockpit, the cooler its cockpit environment. Figure 39 shows that the cockpit's vertical thermal gradient can change as much as 1.87°F/in. It could be concluded that the pilot's right and left consoles experience lower temperatures while nonoperating than does the instrument panel under the same conditions. It should be stated that evidence disclosed in Ref. 6 indicates strongly that the cockpit temperature follows the open-canopy trend shown in Fig. 37, down to the human comfort range of 70 to 100°F chosen by the pilot and controlled by his cockpit air-conditioning equipment. This would indicate that the actual environment of aircraft instrumentation would be that of the desert atmosphere and the human comfort range chosen by the pilot during daytime flights. Under these conditions the extreme temperature would be well under 140°F.

WINTER

The air temperature in the closed cockpit of the parked F9F aircraft conformed to the expected over-all thermal pattern. It can be thought of as air in a chamber with a vertical temperature gradient. However, the temperature of the entrapped air in this instance varies little from canopy to floor. Even in cases of an extreme outside air temperature rise, the differential from canopy to floor never exceeded 10°F.

It can be concluded, therefore, that the heat radiation from an arctic-based aircraft is not greater than normal. The aircraft does not radiate excessively into the −100°F upper atmosphere, a condition that would tend to induce a large gradient, showing extreme low temperatures at the canopy, rising to near ambient air temperature at the floor of the cockpit. The aircraft responds directly to the temperature of the surrounding air, as evidenced by the cockpit's small vertical gradient.

The directional heading of the parked aircraft seems to have little or no effect on cockpit temperatures. The most severe condition is a northern heading; the least severe is an eastern or western heading. This is chiefly because of the shallow angle the sun makes with the horizon during the arctic winter. The slant of the windshield and the back of the canopy allow little of the sun's radiation to enter the cockpit. The near normal exposure of the canopy sides would allow the maximum radiation influx during the extremely short hours of daylight.

One of the expected findings of the test series was the effect of prevailing weather conditions on the minimum cockpit temperatures. Besides minimum standard air temperatures being the chief thermodynamic driving force, as would be expected, overcast skies tended to produce "warm" weather. When the sky cover dissipated, the standard air temperature reflected the effects of radiation into the upper atmosphere.

The ice cover that forms almost instantly on a rapidly cooling aircraft when it is initially parked outside in temperatures lower than −30°F serves as a cover or "cocoon" that retards the radiation of heat from the aircraft. It presents the same type of radiation barrier to the aircraft that clouds do to the earth. A cover of snow, of course, has the same insulating effect.

The data collected during this study indicate that the minimum qualifying temperature for aircraft instruments of −65°F with a trend toward −80°F is far too severe. At no time during the history of the Fairbanks Weather Station has any temperature lower than −66°F been recorded (see Appendix B, Table 7). It would seem that any temperature at this level does not represent a realistic appraisal of the actual exposure to which the instruments are subjected during their actual in-service life. As was stated before, aircraft in an arctic environment will not start if left out in the cold air, and, therefore, are kept in standby shelters until ready for flight. It seems unrealistic that aircraft instruments be designed for maximum efficiency at −65 or −80°F, when seldom, if ever, will they be exposed to temperatures even approaching this level.

From the results obtained during this test series, it is recommended that a minimum qualifying soak temperature of −40°F be used for aircraft instruments. For an arctic-based aircraft, this temperature would give 95% safe coverage during the entire year. For aircraft based in a location where these minimum temperatures are never experienced, this qualifying temperature should give 100% coverage.

Appendix A

METEOROLOGICAL DATA PROMOTING MAXIMUM COCKPIT TEMPERATURES

WEATHER REPORTING SYMBOLS

Sky cover and ceiling symbols are as follows:

○ Clear: less than 0.1 sky cover
⦶ Scattered: 0.1 to less than 0.6 sky cover
⦷ Broken: 0.6 to 0.9 sky cover
⊕ Overcast: more than 0.9 sky cover

Figures preceding symbols are heights at base of clouds in hundreds of feet above station.

Example: 70⦷ is broken sky 7,000 feet above station.

Letters serving as notations on ceiling heights are

E Estimated
M Measured

Example: E 70 is estimated 7,000 feet reported as ceiling.

Wind directions are shown as follows:

↓N	←E	↑S	→W
↙NE	↖SE	↗SW	↘NW
↓↙NNE	←↖ESE	↑↗SSW	→↘WNW
←↙ENE	↑↖SSE	→↗WSW	↓↘NNW

Speed in knots follows direction arrows. C indicates "Calm."

METEOROLOGICAL PARAMETERS

At the NOTS site, there were geographical and meteorological factors (Fig. 45) that possibly influenced the test readings on the cockpit temperatures and contributed to the recording of maximum temperatures in August and September instead of June and July. The highest reading recorded in the cockpit at the pilot's head level was 181°F on 12 September. (This was from a south-pointed test vehicle. When parked facing this direction, an aircraft cockpit, as a whole, is subject to the worst possible solar radiation and temperature extremes.) On this day, there was a wall of clouds from the north to the west with their bases sitting on the mountains towering to the north of the valley.

The record of 10 September shows a ring of clouds sitting on the mountains surrounding the Indian Wells Valley although visibility was

unlimited overhead. This would indicate that conditions of highest temperatures with closed cockpits are due to reflections of the sun's rays off the surrounding clouds into the Valley proper. Figure 45 shows a bird's-eye view of the topography of the Indian Wells Valley. The prevailing air currents leave this Valley cloudless although cloud cover and even precipitation are reported for all four quadrants.

Although it would seem that the El Centro location with higher ambient air temperatures would produce the extreme cockpit temperatures, experiment has shown otherwise. The summer weather in Imperial Valley is cloudless or with moving cloud formations. The clouds are very high and present no reflective surfaces for focusing the sun's rays into the Valley.

This is advanced as a reason for the difference in cockpit temperatures encountered in the test series. The theory is unproved and the author would welcome a thorough investigation of this theory.

The observed weather data for the 14 days of extreme temperature experienced during the 1960 test season are shown in Tables 5 and 6.

FIG. 45. Aerial View of NOTS, China Lake, Showing Mountainous Perimeter.

It would be expected that a clear-sky day with no clouds in sight in the middle of summer would give the maximum exposure. According to Tables 5 and 6, the day that would produce the maximum cockpit environmental temperatures would have some scattered clouds at about 6,500 feet. The humidity would be 20% or less, and if there were any wind it would be a light breeze. The ground visibility would be excelent. The barometer would read about 29.99 inches of mercury, which is typical of a fine desert day. The peak temperature would occur between 1300 and 1400 hours, Pacific daylight time.

It is interesting to note that 19 August, fifth in rank in Tables 5 and 6, was the first day without partial cloud cover. The ninth to the thirteenth days of the 14 days of maximum cockpit temperatures had this same sky condition; the fourteenth day was somewhat overcast.

These observations indicate that maximum cockpit temperature should be experienced in the latter half of the summer season.

TABLE 5. SURFACE WEATHER OBSERVATIONS AS RECORDED BY NAF WEATHER ROOM, CHINA LAKE

Date	Rank	Time	Dry-bulb temp., °F	Wet-bulb temp., °F	Relative humidity, %	Visibility, mi	Cloud cover	Wind, knots	Altimeter setting, in.
12 Sept.	1	1400	102	69	17	15+	65 ⦶	10 SSW	0.991
11 Sept.	2	1400	99	70	24	15+	60 ⦶	C	.999
9 Sept.	3	1400	101	69	20	15+	E 65 ⦶	4 NNW	.995
12 Aug.	4	1400	106	70	16	15+	70 ⦶/⦶	8 SSE	.985
19 Aug.	5	1400	104	66	11	15+	○	6 SSW	.982
10 Sept.	6	1300	96	67	22	15+	70 ⦶/⦶	8 NW	.000
15 Sept.	7	1300	94	60	13	15+	○	4 SW	.989
11 Aug.	8	1400	104	70	17	15+	65 ⦶	4 WSW	.999
7 Aug.	9	1400	108	67	10	15+	○	2 N	.987
20 Aug.	10	1400	104	64	9	15+	○	4 W	.974
7 Sept.	11	1300	92	59	11	15+	○	9 SSW	.984
18 Aug.	12	1400	101	62	8	15+	○	6 S	.986
5 Sept.	13	1300	95	61	11	15+	○	13 SSW	.986
8 Sept.	14	1400	97	63	13	15+	1 ⊕	C	0.991

TABLE 6. Surface Weather Observations as Recorded by NAF Weather Room, China Lake

Data recorded 1 hour before those given in Table 5.

Date	Rank	Time	Dry-bulb temp., °F	Wet-bulb temp., °F	Relative humidity, %	Visibility, mi	Cloud cover	Wind, knots	Altimeter setting, in.
12 Sept.	1	1300	101	68	18	15+	70 ⦶	4 ESE	0.994
11 Sept.	2	1300	94	68	.25	15+	60 ⦶	3 E	.001
9 Sept.	3	1300	98	69	23	15+	E 65 ⦶	5 W	.998
12 Aug.	4	1300	105	70	17	15+	70 ⦶	8 S	.987
19 Aug.	5	1300	101	65	11	15+	○	8 S	.984
10 Sept.	6	1200	95	67	23	15+	70 ⦶/⦷	9 WNW	.002
15 Sept.	7	1200	91	58	14	15+	○	4 WSW	.992
11 Aug.	8	1300	104	70	20	15+	65 ⦶	5 ESE	.002
7 Aug.	9	1300	105	66	10	15+	○	5 SW	.991
20 Aug.	10	1300	103	65	11	15+	○	3 E	.976
7 Sept.	11	1200	91	58	10	15+	○	13 S	.985
18 Aug.	12	1300	100	62	7	15+	○	5 SE	.990
5 Sept.	13	1200	92	60	12	15+	○	3 SE	.989
8 Sept.	14	1300	95	61	11	15+	1 ⊕	2 E	0.993

Appendix B

METEOROLOGICAL DATA PROMOTING MINIMUM COCKPIT TEMPERATURES

by

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Major, U. S. Army Signal Corps

Commanding Officer
Signal Corps Meteorological Team
Fort Wainwright, Alaska

DAILY TEMPERATURE RANGES, WINTER 1961-62

Figure 46 indicates the daily temperature ranges recorded during the 1961-62 winter season at Fairbanks, against a background of the highest and lowest daily temperatures recorded at the U. S. Department of Commerce Weather Bureau Station, Fairbanks. It indicates the great variability of temperatures during an interior Alaskan winter.

The extreme temperatures shown in Fig. 46 are the highest and lowest temperatures recorded for that particular date. The average extreme range of temperature that has been experienced on any date (the difference between the record high and record low temperature recorded for that date) seems to be 80-90°F. The greatest difference experienced for one composite day is 112°F for 5 December, the high temperature being recorded in 1934 (58°F), and the low temperature being recorded one year later in 1935 (-54°F).

During the 1961-62 winter season, two new record highs and 12 new record lows were established for the Fairbanks area. Ten of the new lows occurred between 21 and 30 December. It is readily visible in Fig. 46 that only one other composite cold snap has been more severe since these records have been kept (occurring in 1934). Table 7 gives the exact date of each of the record low temperatures as depicted in Fig. 46.

A given weather condition, and, therefore, the corresponding temperature regime, will very often dominate the area for only a few days during the winter. In the control of temperature during the winter, insolation plays a much smaller role in this area than in the temperate latitudes. Obviously, this is especially true during the latter part of December.

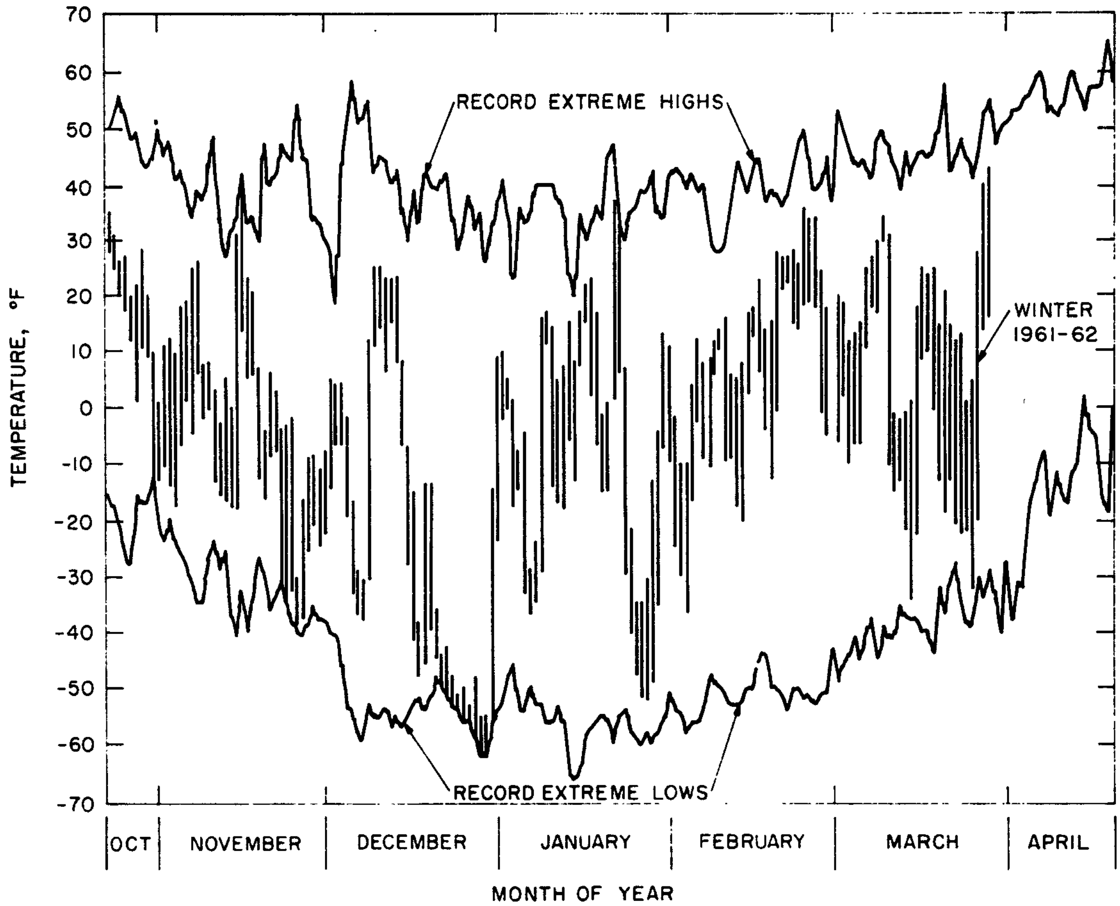

FIG. 46. Comparison of Daily Temperatures Recorded at Fairbanks During Winter 1961–62 With Record Highs and Lows for Those Dates.

AVERAGE WIND SPEEDS

Figure 47 gives the average daily wind speed during winter 1961–62 in the Fairbanks area. Extreme cold-weather conditions are normally associated with low wind speeds. It can be seen that the high wind "spikes" are few in number.

PERCENTAGE OF TIME BELOW SPECIFIED TEMPERATURES

Figure 48 shows the probability of temperatures that occur, however briefly, during the winter months in the Fairbanks area. Because of the high degree of variability of winter temperatures in this area, any given winter could vary significantly from these probabilities. It can be seen that −25°F temperatures have an 18% maximum chance of occurring

TABLE 7. RECORD MINIMUM TEMPERATURES RECORDED AT FAIRBANKS, ALASKA, OVER A 32-YEAR PERIOD (1930–61)

Day	November		December		January		February		March	
	Min. temp., °F	Year	Min. temp., °F	Year	Min. temp., °F	Year	Min. temp., °F	Year	Min. temp., °F	Year
1	–24	1943	–40	1956	–53	1934	–54	1947	–49	1956
2	–20	1945	–41	1935	–48	1934	–55	1947	–46	1956
3	–24	1945	–46	1935	–46	1934	–58	1947	–44	1956
4	–26	1945	–53	1935	–54	1932	–56	1947	–41	1951
5	–28	1955	–54	1935	–54	1932	–56	1947	–45	1956
6	–31	1956	–58	1935	–50	1959	–52	1953	–40	1956
7	–25	1956	–59	1935	–53	1952	–48	1939	–38	1956
8	–35	1956	–53	1935	–53	1952	–49	1936	–45	1956
9	–27	1958	–55	1935	–56	1952	–50	1936	–39	1956
10	–24	1955	–55	1935	–56	1952	–52	1932	–41	1930
11	–29	1930	–54	1935	–53	1934	–53	1932	–41	1930
12	–26	1956	–57	1935	–56	1934	–53	1932	–35	1959
13	–37	1952	–55	1946	–65	1934	–52	1950	–37	1959
14	–41	1956	–57	1946	–66	1934	–50	1950	–38	1959
15	–33	1956	–55	1946	–64	1937	–50	1950	–38	1959
16	–40	1956	–53	1946	–58	1934	–44	1950	–40	1959
17	–35	1956	–52	1933	–57	1947	–44	1937	–40	1959
18	–27	1931	–54	1933	–56	1947	–50	1937	–44	1930
19	–30	1942	–52	1933	–55	1947	–50	1956	–32	1959
20	–36	1942	–48	1933	–56	1952	–51	1932	–37	1959
21	–34	1960	–49	1961	–60	1934	–54	1932	–31	1959
22	–31	1961	–51	1961	–55	1934	–50	1932	–28	1944
23	–35	1950	–53	1961	–54	1934	–50	1932	–34	1935
24	–38	1950	–54	1961	–57	1934	–52	1932	–38	1935
25	–40	1950	–56	1961	–59	1934	–51	1932	–39	1935
26	–41	1942	–56	1961	–60	1934	–53	1932	–30	1935
27	–39	1942	–58	1961	–58	1933	–51	1932	–34	1938
28	–36	1930	–62	1961	–60	1933	–51	1932	–29	1944
29	–38	1941	–62	1961	–58	1933	–43	1956	–33	1944
30	–38	1935	–57	1961	–56	1947	....	....	–40	1944
31	......	....	–54	1933	–51	1947	......	....	–28	1944
Lowest	–41	1956	–62	1961	–66	1934	–58	1947	–49	1956

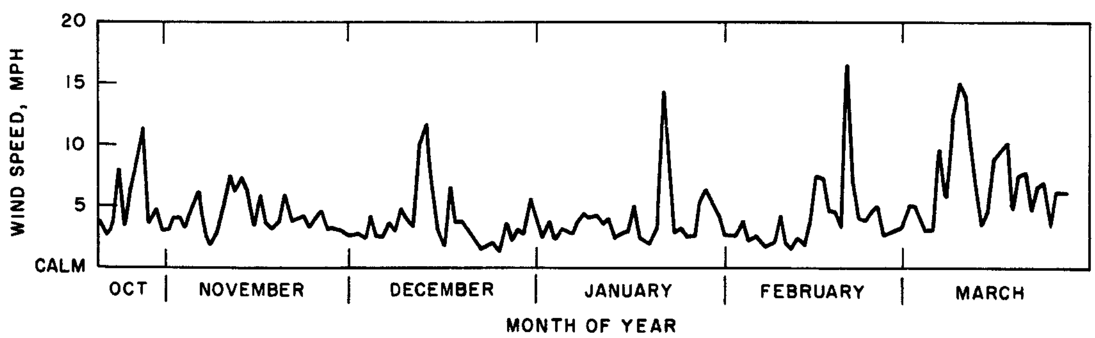

FIG. 47. Average Daily Wind Speed at Fairbanks During Winter 1961–62.

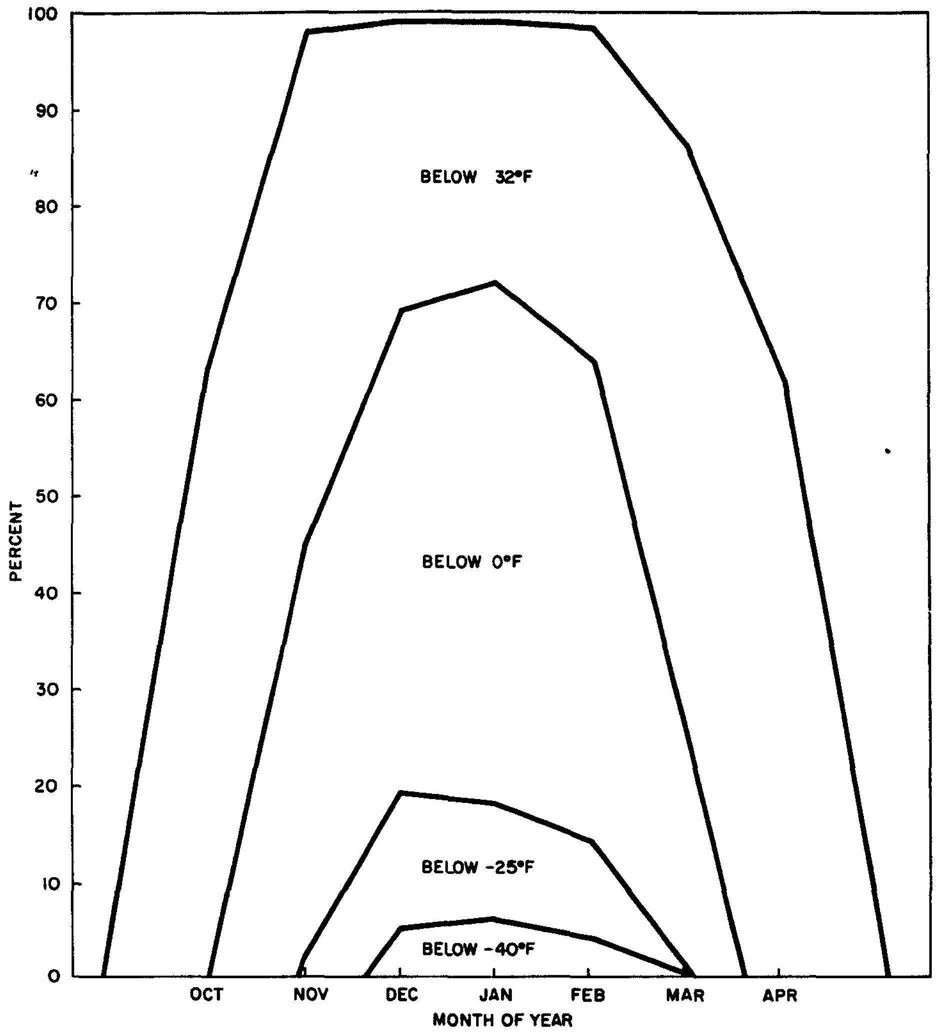

FIG. 48. Percentage of Time Below Specified Temperatures at Fort Wainwright, Alaska.

even during the dead of winter. A −40°F temperature has a 5% maximum chance of occurring, and a −65°F temperature would seem to have less than a 1% maximum chance of occurring. The minimum temperatures that have been recorded at Fairbanks since weather records have been kept are −66°F in January 1934; −58°F in February 1947; −49°F in March 1956; −41°F in November 1956; and −62°F in December 1961. It should be noted that these temperatures are record minimums, not common values.

FORT WAINWRIGHT-FORT GREELY COMPARISON

When discussing subarctic weather conditions, a comparison of the climate of the Fairbanks area with that of the climate at nearby Fort Greely is needed. Figure 49 shows mean, or average, values of

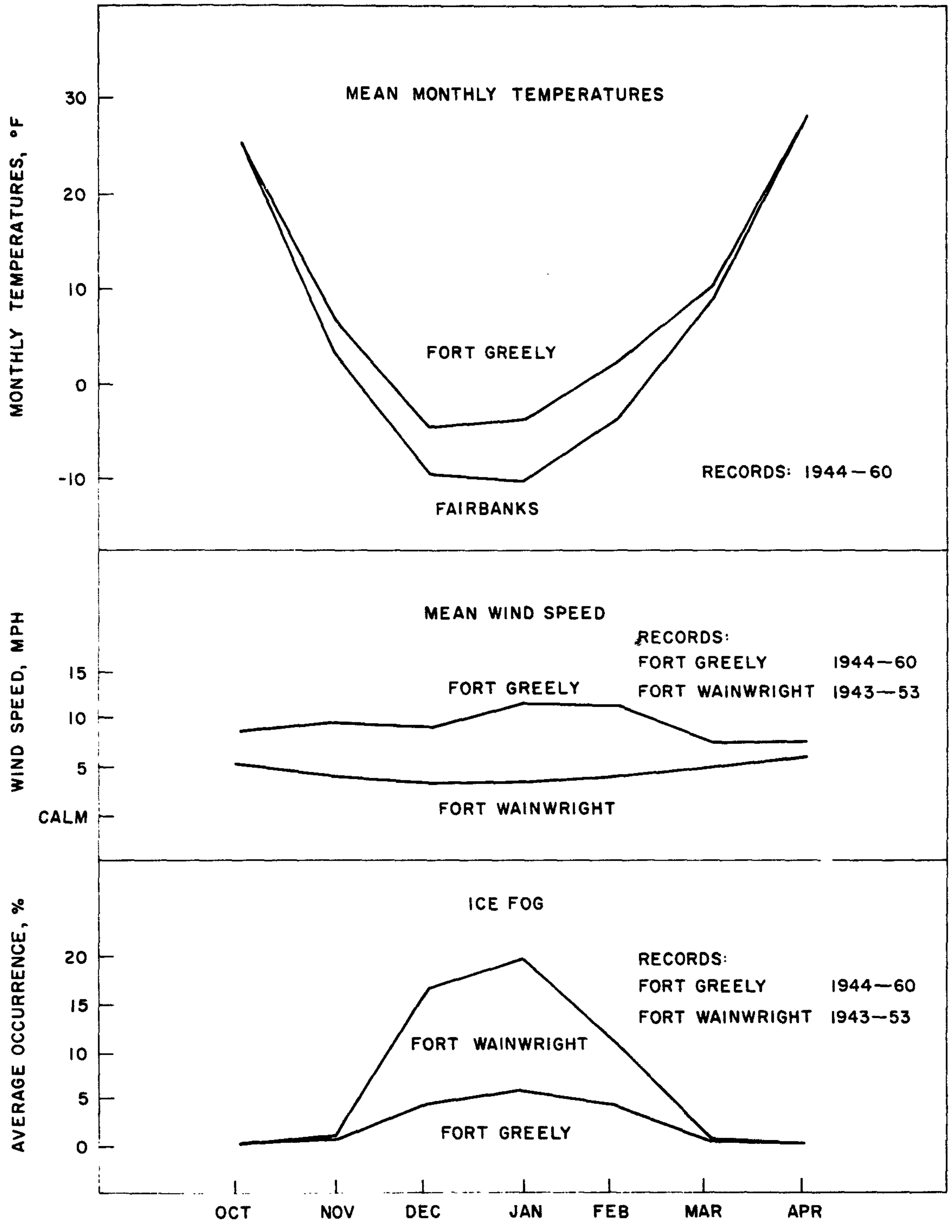

FIG. 49. Fort Greely—Fort Wainwright Climate Comparison.

monthly temperature, wind speed, and ice fog occurrence for both installations. These mean comparisons indicate that Fort Greely has a slightly warmer climate during the winter than that found at Fairbanks, Alaska. The biggest difference in monthly mean temperatures is in January when a difference of 6.5°F is shown. Winter wind speeds at Fort Greely average about 5 mi/hr stronger than those experienced at Fort Wainwright. Wind speeds during periods of extreme cold are essentially the same at both stations. After the warming has been well established, the wind at Fort Greely usually becomes quite brisk. The differences shown in ice fog occurrence are attributable mainly to the differences in population in the immediate vicinities of the two posts. Human activity is the main cause of ice fog.

It can be seen that there are definite microclimatic differences when only a few miles are traveled between the two points being measured. The differences are found with changes in altitude and are very pronounced during winter periods of intense cold.

NEGATIVE NUMBERS OF ILLUSTRATIONS

Fig. 1, LHL L060733
Fig. 2, LHL L058771
Fig. 3, not NOTS photo
Fig. 4, top to bottom
LHL L069985
LHL L069983
LHL L069982
Fig. 5, LHL L063577
Fig. 6, none
Fig. 7, LHL L070626
Fig. 8, LHL L069981
Fig. 9–44, none
Fig. 45, LHL L026864
Fig. 46–49, none

BIBLIOGRAPHY

1. Frankford Arsenal, Pitman-Dunn Laboratories Group. Temperature Data on Standard and Experimental Cartridges in Pilot Ejection Devices in a B-47E Aircraft Stationed at Yuma, Arizona, by W. W. Cavell and R. H. Cox. Frankford Arsenal, Philadelphia, Pa., January 1960. 22 pp. (Memorandum Report No. M60-16-1.)

2. Naval Parachute Facility. Temperature Parameters A4D Cockpit. Letter, Code 521 to Code 123, Naval Parachute Facility, El Centro, Calif., 13 December 1960. Final letter report, Serial 737.

3. Paper presented by Howard Schafer, Propulsion Actuated Devices Symposium, 14 June 1961, Frankford Arsenal, Pitman-Dunn Laboratories Group, Philadelphia, Pa., on the subject "Maximum Environmental Temperatures for Mk 1 Mod 0 Rocket Catapult," included in Proceedings.

4. U. S. Army Quartermaster Research & Engineering Command. Atlas of Arctic Environment. Quartermaster Research & Engineering Center, Natick, Mass., March 1961.

5. U. S. Naval Ordnance Test Station. Environmental Tests of Rocket Catapult Mk 1 Mod 0 (Aircraft Ejection Seat), by Howard Schafer. China Lake, Calif., NOTS, March 1961. 54 pp. (NAVWEPS Report 7631, NOTS TP 2368.)

6. ———. In-Flight Environmental Tests of Rocket Catapult Mk 1 Mod 0 (Aircraft Ejection Seat), by Howard C. Schafer. China Lake, Calif., NOTS, November 1961. 10 pp. (NAVWEPS Report 7777, NOTS TP 2758.)

7. ———. Cold-Weather Environmental Tests of Rocket Catapult Mk 1 Mod 0 (Aircraft Ejection Seat), by Howard C. Schafer. China Lake, Calif., NOTS, May 1962. 18 pp. (NAVWEPS Report 7875, NOTS TP 2858.)

8. Wright Air Development Center. Handbook of Environmental Engineering, by E. C. Theiss, H. Mileaf, and F. Egan. Wright-Patterson Air Force Base, Ohio, AFSC, 1961. (ASD Technical Report TR 61-363.)

9. ———. Phase V High Temperature Climatic Test of an F-101A Aircraft, by Robert B. Fendick and Capt. Donald H. Stuch. Wright-Patterson Air Force Base, Ohio WADC, November 1956. 14 pp. (WADC Technical Note 56-404, AD 110599.)

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ABSTRACT. A series of tests was carried out to define more clearly the extreme temperature environments to which aircraft instrument indicators and sensors in Fleet operational aircraft would be

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The report includes 7 tables and 40 graphs. Weather parameters are touched upon as they

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